Physical Science

Lesson01: Principles of Science

Lesson Objectives:

- Student will review and apply the scientific method.
- Students will understand how the logic used in science differs from other disciplines.
- Students will recognize and give examples of inductive and deductive reasoning.
- Students will recognize and give examples of falsifiable and non-falsifiable statements.
- Students will understand the characteristics of valid scientific experiments and evaluate an example experiment based on these characteristics.
- Students will apply critical thinking skills to begin thinking about how observations are measured.

Physical Science

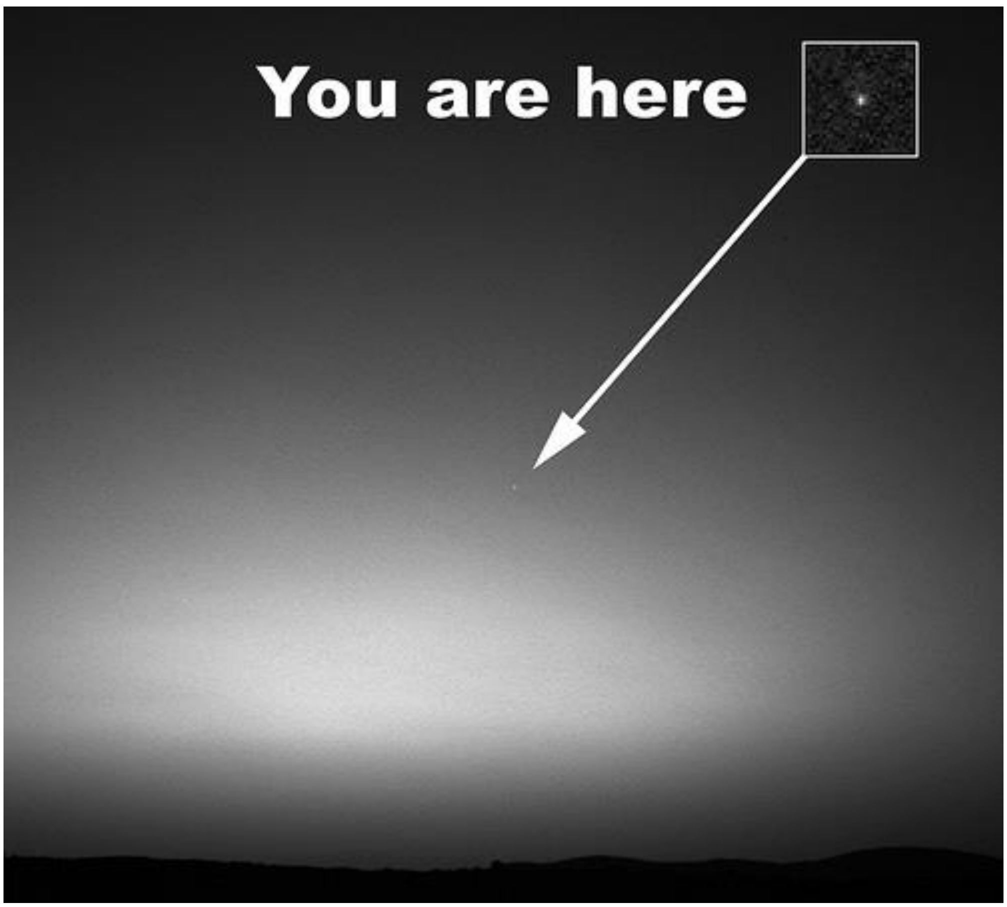
You are probably asking yourself, "What is Physical Science and what will we be learning about in this class?". This is an great question and an excellent place to start our class.

Physical science is the study of energy, nonliving matter, and natural forces. It is the attempt to understand the world/universe we live in, the forces that act upon it, and how we can use this information. This includes many topics from chemistry, physics, astronomy, and geology. Just think for a moment about what this includes... Not only does this include technical jobs such as engineering and design; but every time you use a ruler to measure the length of something, use a measuring cup to bake/cook, boil water, or weigh yourself on a scale (just a few examples) you are doing physical science.

The number of jobs and occupations that are included in physical science is just staggering. The electrician who installed wiring where you live was a physical scientist (even though she or he may not have known it). A weather forecaster is a physical scientist. The mechanic who repairs your car, technician who monitors your drinking water, inspectors who test structural concrete and steel are all physical scientists. Anyone who makes measurements, observations, and or predictions involving energy (such as electricity), nonliving matter (such as water), and natural forces (such as wind) is doing physical science.

Of course, with physical science covering so many topics, we will only be introduced to a limited number of them. Some topics we will discuss include matter, the atom, motion, forces, work and energy. We will talk about electricity, light and sound. Finally we will discuss nuclear fusion and fission. Before we begin, we will review the scientific method.

Welcome to the class! This is an exciting time to be studying science! New technologies are making it possible to see the world and universe in ways that were unimaginable only a generation ago. Here is the **first** image of Earth ever taken from the surface of another planet (the Moon is considered a satellite). It was taken by the Mars Exploration Rover Spirit on March 8, 2004.



Credit: NASA/JPL/Cornell/Texas A&M

The Scientific Method

The Scientific Method (And why this topic will not go away.)

Every science class you take in South Carolina starts with a review of the scientific method. Since it is reviewed over, and over, and over... you probably got the message by now that it is important, for some reason or another. But, What's the big deal with this scientific method and why won't it just go away?

When you watch TV, read a magazine or newspaper, check your email, look in your mailbox or step outside your door, you are bombarded with 'science like' advertising claims. Does any of the following sound familiar?

- Helps control (*insert malady here*) symptoms with regular use.
- Tests confirm that (*insert product name here*) is **best** against (*insert problem here*).
- (*Insert brand name here*) gives you more!
- There's no other (*product here*) like it.
- Now made with (*some scientific sounding word here*) to improve bad breath.
- 33% more cleaning power than the leading brand.
- Gets you ripped in only (*insert time here*) minutes a day!
- The brand recommended by 9 out of 10 (*insert job title here*).

Credit: CC Pheezy

Most of these sound like they were generated by 'hard core' scientists wearing lab coats (sometimes they even have actors wearing lab coats in the commercials), with pocket protectors in some remote lab (probably very secret, high security facility nestled away in the mountains). After all, it has*superlativeol* in it... it has to be good, right? Common sense tells you these competing claims can't *all* be right.

There is a real danger with people (the general population) thinking that these are all based in scientific research. They may then conclude that if these are all bogus, then is most science just a matter of opinion or bias?

Here is where the **scientific method** comes to our rescue. (Cue inspirational music - the scientific method arrives, wearing a cape, with the jubilant cheering of scientists in the background.) The scientific method not only helps us determine *how* to "do science", it also helps us determine what is science (vs."junk science", "pseudoscience", or a number of other terms that are used).

Keeping it Real

Before we break down the scientific method into steps, we should first talk about sources of scientific information. (And yes, this is part of the standards, you are expected to be familiar with this.) Scientists (this includes students studying science) are expected use additional information and data when they are planning and conducting investigations. There are many possible sources of information, but not all of them are equal. Scientists look for sources of information that are:

- **credible** - trustworthy
- **accurate** - correct, based upon supported data
- **relevant** - applicable, related to the topic of investigation

Many sources are not based upon credible scientific research. These sources may contain information that is biased and not accurate. For example, many non-profit organizations and corporations may present data that is biased and completely ignore experiments when the outcome does not support their cause. The ***best*** sources of information are articles published in peer-reviewed (reviewed by a panel of respected scientists) journals. When you are searching for reliable information on the internet, credible information can often be found on government web sites (ending in ".gov"). These include such resources as NASA, national laboratories, and government agencies.

Q1. You are watching the news and see a news report about ground water contamination. Curious, you want to know more about how it may effect your community. From the following list of sites, select the **one** most likely to contain accurate information about hazardous waste sites. Use this site to answer the parts of this question:

- http://en.wikipedia.org/wiki/Cleanup
- http://www.handsonhealth-sc.org/
- http://www.epa.gov/
- http://www.answers.com/topic/superfund

  1. Briefly, what is the Superfund and when was it started?
  2. What Region is South Carolina in? What other states belong to this Region?
  3. What is the name of the Superfund site that is closest to your home (and what address and/or zip code did you use to locate it)?

4. Which site did you use to answer these questions? Why did you select it? (Why did you believe this would be the more *credible, accurate and relevant* site?)

Breaking it Down

The scientific method is the process scientists use to explore the world around us and predict how it works. The process is ongoing and never-ending. Scientists use the scientific method to develop better, more useful hypotheses about how things function. A **hypothesis** is *an explanation of an observation or experimental result that can be tested*.

When using the scientific method, you follow these general steps:

1. Observation: You see, hear, smell, taste, feel or calculate something. While working on your assignment on the computer, you suddenly *see* that the monitor turns black and you *hear* no noise from the computer unit.

2. Question: What is wrong with the computer and its monitor?

3. Hypothesis: The power went out.
Note: Many times scientists come up with more than one hypothesis right away. In this case, another one could be: The computer crashed.

4. Prediction: If the power went out, then the lights should not work either.

5. Test: Turn on a light in the house to find out whether it works.

6. Conclusion: Was the hypothesis supported or disproved?

The test will either support your hypothesis because the lights do *not* work **or** the test will not support your hypothesis because the lights *do* work, and you will have to modify your hypothesis or come up with a completely new one.

Q2. Your uncle Jim makes a salad dressing that you really like. After Sunday's dinner he gives you a bottle with some of the dressing to take home to use during the following week. When you take the bottle out of the fridge next day, you see that there are different layers of fluid. Your first instinct is to call uncle Jim and ask him whether the dressing went bad. However, you remember reviewing the scientific method and want to use it to find out what happened to the dressing.
Write out each of the 6 steps above applying the scientific method to this observation.

1. observation:
2. question:
3. hypothesis:

4. prediction:
5. test:
6. conclusion:

Q3. Your friend, Barbara, tells you she is using a new fertilizer on her roses. She believes this new fertilizer, "Mega Rose", is making her roses grow faster and flower more than your roses. How could you use the scientific method to decide if you should start using "Mega Rose" on your roses, too?
Write out each of the 6 steps above applying the scientific method to this observation.

1. observation:
2. question:
3. hypothesis:
4. prediction:
5. test:
6. conclusion:

Inductive and Deductive Reasoning

When a specific observation (in our case that the computer monitor went black) leads to a general hypothesis, we call this inductive reasoning. Think of inductive reasoning as little to big. Many *little* (or specific) facts lead to a *big* (or general) principle.

Example:

Credit: Jeremy Vandel

Credit: Joost J.Bakker IJmuiden

Credit: Kristine Paulus

This ladybug has six legs; This grasshopper has six legs; This firefly has six legs. So do *all* insects have 6 legs?

When the general hypothesis leads to specific predictions (in our case, if the power is out the lights may not work either), we call this deductive reasoning. Think of deductive reasoning as big to little. One *big* (general) principle leads to many *little* (specific) predictions.

So, using deductive reasoning:

- I know that adult insects have six legs, therefore:
  - I bet if I go into the yard and catch a ladybug, it will have six legs.
  - If I catch a grasshopper, I bet it will have six legs.
  - If I catch a firefly, I bet it will have six legs, too.

Here's a trick to help you remember which is which:
*In*ductive is *In*creasing (little to big)
*De*ductive is *De*creasing (big to little)

Notice that the scientific method uses both kinds of reasoning. Inductive reasoning is used when you take the specific observations and make a general hypothesis. Then deductive reasoning is used when you figure out a way to test that hypothesis. Then inductive reasoning is used again when you gather the data from your test and use it to make a conclusion about your hypothesis.

Although science uses both types of reasoning, it relies much more heavily on *inductive reasoning*. Notice that the scientific method always starts with an *observation*. You see, hear, smell, touch, taste, or calculate something. The scientific method never *starts* with a principle; it only develops a principle (called a **theory** in science) after much observation and hypothesis testing.

Ideally, scientific experiments never try to *prove* that a theory is correct, they seek to show the theory is incorrect, or *disprove the theory.* Whenever this happens (and it happens very frequently), the experiment must be repeated. Other labs and scientists try to reproduce the experiment, also. If numerous labs are able to reproduce the experiment that disproved the theory it is usually modified to account for the new data (or observations), or it could be thrown out completely (and possibly be replaced).

There are other fields of knowledge that use *deductive reasoning* more heavily. Subjects such as philosophy, literature, art, and religion begin with widely accepted principles and deduce specifics from there. For example: "You shall not steal" is a principle (big) and we may use it to guide a specific decision (little) about whether to stop at the checkout counter and pay before we leave a store with something. These are great ways to develop, enjoy, and guide our lives as whole human beings. They are no less important than science, they just approach knowledge differently.

Q4. Give one example that is not found in the lesson for each:

a.) inductive reasoning
b.) deductive reasoning

Hypothesis - Theory - Scientific Principle or Law

A hypothesis that is repeatedly tested and verified is strengthened, in particular, if the tests are done by different scientists. However, billions of positive tests still do not verify the hypothesis. But, a single repeatable failure of the test can prove the hypothesis false (*disprove the hypothesis*).

Scientists are constantly applying new technology (something we will discuss in a later lesson) to their studies. Sometimes, these new technologies allow scientists to conduct experiments (tests) previously impossible. Armed with better equipment and techniques it is not uncommon to disprove a hypothesis.

A **theory** is a hypothesis that has been scientifically acknowledged to explain phenomena and observations. It is usually not a static construct but undergoes cycles of modifications as new ways of testing are developed.

A scientific principle or **law** is a theory that has resulted in true predictions over an extended time and is almost universally accepted. However, these principles are sometimes still referred to as theories. Even gravity is sometimes referred to as a theory in scientific lingo.

Q5. Find out about one theory in physics and one theory in chemistry and report your findings here.

Q6. Find out about one scientific principle or law in physics and one scientific principle or law in chemistry and report your findings here.

Falsifiability

Falsifiability is one of the important principles of science. Falsifiability is the logical possibility that something can be disproven. A question must be falsifiable to fall into the realm of scientific inquiry. Lets look at these two general principles:

1. Gravity is a property of all matter.
2. Leos are charismatic leaders.

In order to be studied by science, a principle must be falsifiable. Which of these is falsifiable? For the first statement, if any matter did not behave according to the theory of gravity by showing an attraction to other matter, then the principle of gravity would need to be modified. (Physicists are in the process right now of dealing with this issue as they try to figure out the properties of "dark matter.") So yes this is falsifiable. It can be found out to be false.

On the other hand, if a person born under the sign of Leo, between July 23 and August 22, was not a charismatic leader, the situation is handled differently. Instead of saying, "Well, maybe this principle isn't quite right; how can we fix it?" an astrologer would say "Well, just because you *think* that you are not a charismatic leader does not mean that Leos are not charismatic leaders. It means you are suppressing your natural leadership abilities." This could possibly be true about someone, and it's interesting to think about. But no matter how many observations contradicted the principle that Leos are charismatic leaders, it would not prove the principle false. This means that number 2 is NOT falsifiable. Therefore, it does not count as science. Figuring out whether or not it is true is none of our business in science, even when it has to do with the movement of planets.

NOTE: That something is "falsifiable" does not mean it is false; rather, it means that ***if*** the statement were false, we could show that it was false.

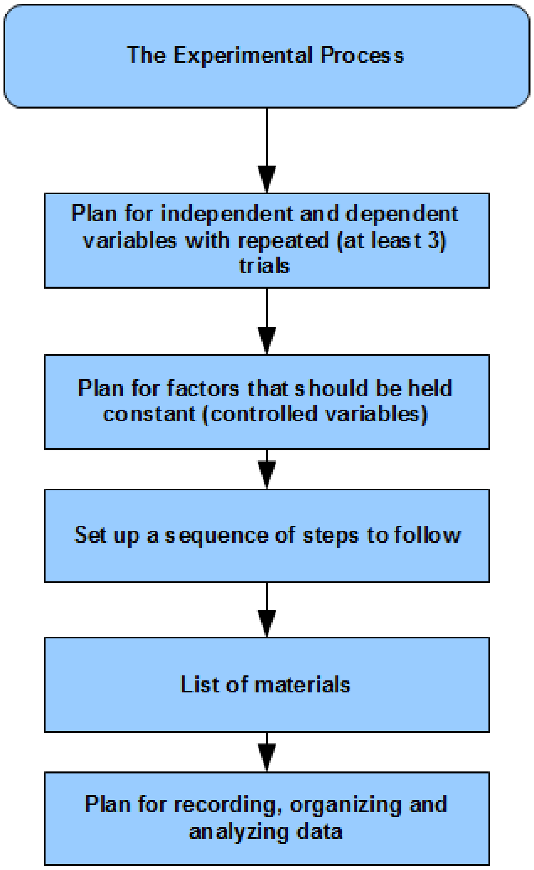
Q7. Come up with your own examples of a falsifiable statement and a non-falsifiable statement. For each one, explain how it can or cannot be proven false.

Q8. Find out what is meant by the term pseudo-science and give an example not found in this lesson.

Scientific Experiments

Recall step 5 in the scientific method. In step 5, we test our hypothesis and prediction. There are several ways to do this, and the correct way depends on the question being asked and the specific scientific discipline we are working in. In social sciences, a survey might be a good way to test a hypothesis. In physics, we might run a computer simulation or work a mathematical equation to test a hypothesis. In biology or chemistry we might perform an experiment.

Sometimes the word *experiment* is used in everyday life to simply mean "to try something." However, we will find throughout this class that the scientific meaning of certain words is sometimes a little bit, or a lot, different from the everyday meaning. In science, an *experiment* is a very specific way to test a hypothesis. In an experiment, we want to know if a change happens, and we want to be sure we can identify *what* caused a change to happen. To do this we isolate a variable we are interested in, make a difference to that variable while keeping other variables the same, and see what changes as a result of that difference. Click on this link to learn more about scientific experiments. The following graphic may help you organize how to plan for an experiment.



Putting the Steps Together

Credit: Cyron

1. **Observation:** When I go outside, I noticed that on different nights and times crickets chirp at different rates (the frequency of their chirps changes).
2. **Question:** Is there a factor that affects the chirping rate of crickets?
3. **Hypothesis:** After reading some reference books and searching on the internet I believe that air temperature may be affecting the rate at which the crickets chirp. My hypothesis will be, "*If air temperature is increased, the rate that a cricket chirps will increase.*"

4. **Prediction:** If I measure the rate at which crickets chirp at night, the rate will vary with temperature. The rate at which crickets chirp and the temperature will be directly proportional (we will learn about direct proportion in Lesson 3 - Data Analysis).
5. **Test:**
    - Independent variable: Temperature
    - Dependent variable: Rate at which crickets chirp
    - Control variables:
        - Atmospheric pressure - 760 mm
        - Wind speed - 2 m/sec
        - Humidity - 15 %
    - Materials:
        - Access to weather data
        - Crickets in an area/environment where they can be observed
        - Timer/stopwatch
    - Procedure (Steps)
        - Check the current weather on the Weather Channel or internet. Record the air pressure, relative humidity, wind speed and humidity.
        - If the control variables are each within 10% of their target locate a cricket and record the number of chirps the cricket makes in 1 minute and record this measurement (along with the temperature) in a table. Repeat at least three times (three trials).
6. **Conclusion:** Was your hypothesis supported or disproved?

Q9. Janice has a geranium in a flowerpot, and after a while it dies. Janice thinks, "I wonder if it is because of the type of potting soil I used?" So she goes to the store and buys a new geranium and a different type of potting soil to plant it in. She also waters this new geranium every other day and is careful not to forget about it like she did before. After the plant survives for one year, Janice decides that her experiment proved that this new brand of potting soil is excellent and recommends it to all her friends. Use the information in the link above and:

Credit: cincooldesigns

- Explain why Janice's experiment is actually **NOT** good enough to make the interpretation that she made?
- Help Janice out by designing an experiment for her. Include all steps of the scientific method and the information on the link above. Be sure to specifically list all your variables and which type each is.

Q10. What is a "control group"? Why does an experiment need to have a control group? (Hint: Look in the link above.)

Additional Questions

Use the knowledge you have gained from this lesson as a basis for further investigation. Use your logic, or do some additional research to answer the following questions:

Q11. You may have learned that insects have six legs. If you spend the rest of your life catching bugs and counting their legs, will you ever find one that does not have six legs? Explain your answer.

Q12. Do some research to find out what the difference is between experiment data and experiment result. Please, explain your answer including an example. (Don't forget to site your source!)

Q13. Select one of the following hypotheses.

- If air pressure is lowered then water will boil at a lower temperature.
- If you apply a constant force, an object with smaller mass will accelerate more than an object with a larger mass.
- If you increase the temperature of a cup of water, more sugar will dissolve in it.
- If salt is added to tap water it will boil at a higher temperature.

Apply the scientific method (write out each of the six steps) to the hypothesis you selected. Design a test (experiment) for your hypothesis remembering to list your variables, steps, materials and plan for data.

Grading Rubric:

Note: For this class it is necessary to post the questions over each answer. Failure to do so will result in being asked for a revision.

To get a 10: All answers are correct, thorough, and clearly written/drawn within 2 revisions. All writing is grammatically correct and all lesson requirements have been met.

To get a 9: In 3 revisions, all answers are correct, thorough, and clearly written/drawn. All writing is grammatically correct and all lesson requirements have been met.

To get an 8: In 4 revisions, all answers are correct, thorough, and clearly written/drawn. All writing is grammatically correct and all lesson requirements have been met. -OR- In 2 revisions, 4 or fewer minor grammatical errors remain (missing commas, typos, or other mistakes that do not impede clarity)

To get a 7: In 5 revisions, all answers are correct, thorough, and clearly written/drawn. All writing is grammatically correct and all lesson requirements have been met. -OR- In 3 revisions, 4 or fewer minor grammatical errors remain (missing commas, typos, or other mistakes that do not impede clarity)

To get a 6: In unlimited revisions, all answers are correct, thorough, and clearly written/drawn. All writing is grammatically correct and all lesson requirements have been met.

To get a 5: Plagiarism - purposeful or mistaken, which will lower your final grade for the course (so be very careful when posting your work!); lack of effort, disrespect, or attitude (we are here to communicate with you if you don't understand something); lesson requirements have been met.

No grade will be given for incomplete work.

Assignment:

Copy and paste all of the questions in the lesson above into the text box below. Below each question, answer it in complete, grammatically correct sentences.

Do not submit text that you have copied from sources, including websites. **All of your work should be in your own words.** Using copied text would be considered plagiarism. For more information, review our page on Plagiarism and Citation. When citing your sources, be sure to use the full proper citation format as described in Plagiarism and Citation.