The Scientific Method

Unit: Laboratory & Measurement

NGSS Standards: N/A

MA Curriculum Frameworks (2006): N/A

AP Physics 2 Learning Objectives: N/A

Knowledge/Understanding Goals:

- Understand the scientific method

Language Objectives:

- Understand and correctly use terms relating to the scientific method, such as "peer review"

Notes:

The scientific method is a fancy name for "figure out what happens by trying it."

In the middle ages, "scientists" were called "philosophers." These were church scholars who decided what was "correct" by a combination of observing the world around them and then arguing and debating with each other about the mechanisms and causes.

During the Renaissance, scientists like Galileo Galilei and Leonardo da Vinci started using experiments instead of argument to decide what really happens in the world.

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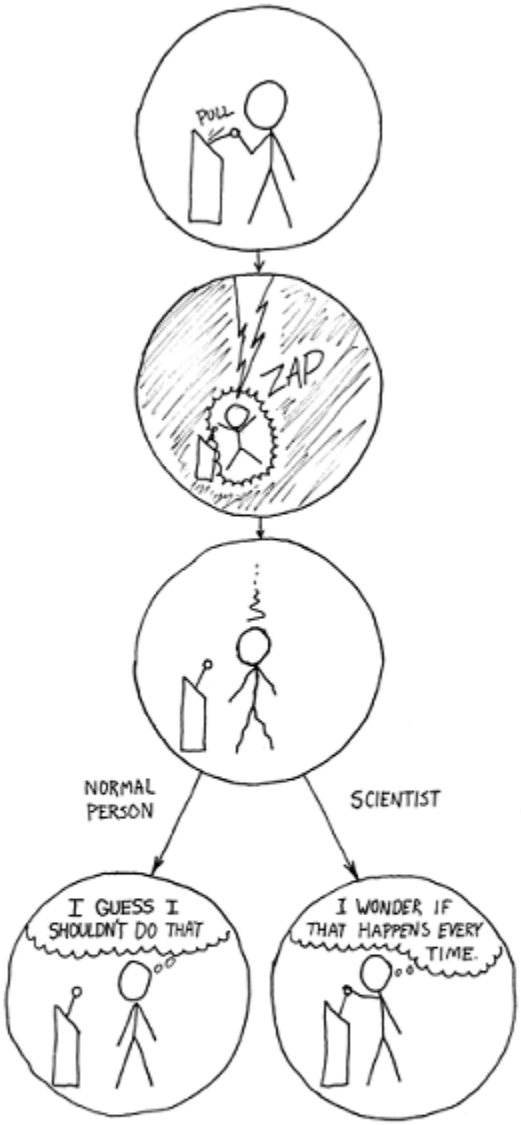
Steps:

Note that although the steps are numbered, there is no "order" to them. I.e., depending on the circumstances, a scientist could end up jumping from just about any step to just about any other step in the process.

1. Observe something interesting.
2. Figure out and perform experiments that will have different outcomes depending on the parameter(s) being tested. You can make a ***claim*** that describes what you expect will happen (sometimes called a hypothesis), or you can just perform the experiment to see what happens.
3. Repeat the experiment, varying your conditions as many ways as you can.
4. If you are testing a claim, ***assume that your claim is wrong.*** Try every experiment and make every observation you can think of that might refute your claim.
5. If your claim holds, try to come up with a model that explains and predicts the behavior you observed. This model is called a ***theory***. If your claim holds but you cannot come up with a model, try to completely and accurately describe the conditions under which your claim successfully predicts the outcomes. This description is called a ***law***.



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6. Share your theory (or law), your experimental procedures, and your data with other scientists. Some of these scientists may:
    a. Look at your experiments to see whether or not the experiments really can distinguish between the different outcomes.
    b. Look at your data to see whether or not the data really do support your theory.
    c. Try your experiments or other related experiments themselves and see if the new results are consistent with your theory.
    d. Add to, modify, limit, refute (disprove), or suggest an alternative to your theory.
    e. Completely ignore your theory and your experiments. (The vast majority of scientists will do this; scientists are busy people who are in no way obligated to spend their time testing other people's theories.)

    This process is called "peer review." If a significant number of scientists have reviewed your claims and agree with them, and no one has refuted your theory, your theory may gain acceptance within the scientific community.

Note that the word "theory" in science has a different meaning from the word "theory" in everyday language. In science, a theory is a model that:

- has never failed to explain a collection of related observations
- has never failed to successfully predict the outcomes of related experiments

For example, the theory of evolution *has never failed* to explain the process of changes in organisms caused by factors that affect the survivability of the species.

If a repeatable experiment contradicts a theory, and the experiment passes the peer review process, the theory is deemed to be wrong. If the theory is wrong, it must either be modified to explain the new results, or discarded completely.

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Note that, despite what your ninth-grade science teacher may have taught you, it is possible (and often useful) to have a hypothesis or claim before performing an experiment, but an experiment is just as valid and just as useful whether or not an hypothesis was involved.

Theories vs. Natural Laws

The terms "theory" and "law" developed organically, so any definition of either term must acknowledge that common usage, both within and outside of the scientific community, will not always be consistent with the definitions.

A theory is a model that attempts to explain ***why*** or ***how*** something happens. A law simply describes what happens without attempting to provide an explanation. Theories and laws can both be used to predict the outcomes of related experiments.

For example, the Law of Gravity states that objects attract other objects based on their masses and distances from each other. It is a law and not a theory because the Law of Gravity does not explain *why* masses attract each other.

Atomic Theory states that matter is made of atoms, and that those atoms are themselves made up of smaller particles. The interactions between the particles that make up the atoms (particularly the electrons) are used to explain certain properties of the substances. This is a theory because it gives an explanation for *why* the substances have the properties that they do.

Note that a theory cannot become a law any more than a definition can become a measurement or a postulate can become a theorem.

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