Experiment 1: The Penny Experiment

Introduction to The Scientific “Method”

Learning Objectives and Outcomes:

1. Relating how science works to what scientists do.
2. Defining key terms used by scientists.
3. Utilizing scientific principles to solve a problem.
4. Determining what happens to the mass of a penny as it circulates through the population.

Introduction:
Many texts, internet sources and even science teachers will carry on about the Scientific Method. You undoubtedly have learned about a rather rigid progression from hypotheses, observations, and experiments to theories and laws, like what is shown in your current chemistry textbook.

But is this really what scientists do? Many working chemists make or modify consumer products. They rarely “test a theory” in their day to day jobs, but may be exhausting themselves trying new combinations of chemicals under different conditions to produce a new drug, plastic or color for paint. Does this mean they are not doing science?

The various “methods” described for science all have one thing in common, which is to require observations or experimental evidence as the backbone of any argument. This is the key to setting SCIENCE aside from other ways of learning.

Why is this important? Back in the old days, the really old days, the “scientists” were actually philosophers. They obtained knowledge by thinking and applying logic. It went like this:

“Meat that is in contact with air becomes spoiled with flies.
Excluding air eliminates the flies. Air must therefore turn into flies.”

No one could argue with this, as it is a rock solid, logical argument. It was thought for a really long time that air turned into flies (until the 1800’s)

Now around the 1700-1800 mark, people became less satisfied with logic. Someone finally thought to test the above logical conclusion by asking the question,

“What if meat is exposed to air, but the meat is screened with fine cloth?”

Aha! No flies! Someone finally did an experiment and tested the logical, thinking conclusion.
Science was finally born, followed by the misleading term “scientific method.” Very few physical or biological scientists sit down with a copy of “The Scientific Method Handbook” and start to work on their problem. But what all good scientists do is base their statements and conclusions on all available observations and experimental evidence. This is the real “method” of science, which is simply a way of learning as compared to belief, logic, emotional, authoritarian and wishful thinking systems.

While the “Scientific Method” rarely follows the typical route from hypothesis → experiment → theory → law, it is necessary to know what the terms mean, because good science does depend upon their definitions. (adapted from http://antoine.frostburg.edu/chem/senese/101/intro/index.shtml)

Observations and experiments:
1. the foundation of the scientific method
2. data can be qualitative or quantitative.
3. data is most useful when collected under controlled conditions
4. data must be repeatable and reproducible

Natural laws
1. descriptions of nature, NOT explanations
2. are not “obeyed” or “broken”
3. often apply only under special conditions
4. summarize patterns in a large amount of data
5. do NOT stem from theories or hypotheses, they are only descriptions of observations
6. The law of gravity only describes that objects attract each other, and move in certain ways. No explanation of why gravity works was included.

Hypotheses
1. tentative explanations designed to guide experimentation
2. a hypothesis must be testable and is rejected or corrected when it conflicts with experiment
3. often confused with predictions of what will happen in an experiment.
4. Example:
   a. Hypothesis: flies don’t come from air and meat, only other flies
      (testable, guides experiment, explains why)
   b. Prediction: filtered air exposed to meat won’t produce flies
      (the logical outcome of the hypothesis, MUST be tested!)

Theories
1. well-tested explanation for experimental data or observations
2. similar to hypotheses, but backed up with evidence
3. explain ALL the data present and successfully predict what will happen in the future
4. A theory does not become a ‘law’ when ‘proved’
5. must be rejected or modified upon valid, conflicting data
6. Example: Evolution is a theory.
   a. Explains how organisms have changed over generations.
   b. Evidence from bacterial resistance to drugs, tuskless elephant herds
   c. Predicts how organisms can evolve in the future, based on genetic changes
7. A theory is an idea that a learned person thinks is so valuable that it should be tested to judge if it is correct under as many circumstances as possible.

Proof in Science
It is important, although possibly alarming, to note that science cannot “prove” a particular theory. A good theory can only explain all of the available data, and predict what can be observed. You will see at least one example in the next few weeks where a theory did just this, but was later shown to be inadequate by the introduction of new data and observations.

It might be somewhat troubling to hear in your first week of class that a scientific theory can be incorrect. Scientists are only humans, so the possibility for error exists. However, science is self-correcting, in that our best explanations (theories) allow for the possibility of conflicting data that will force a change. The best thing about scientists being human is that if you are a human, you can be a scientist!

Many students are familiar with the debate between evolution (a scientific theory), creationism, and intelligent design. The issue won’t be argued here. However, two excellent points can be made regarding the teaching of evolution vs. the other two ideas.

1. Evolution is a scientific theory; it is backed by data and has predictive value. It is impossible to find predictive value in creationism or intelligent design. These two ideas cannot address the question of “Will something else be created or designed?” Evolution can address the question of “Will anything else evolve?” Evolution is therefore a useful tool for a scientist.

2. Creationism and intelligent design rely upon the premise of “we don’t understand it, so it must have been created by a designer.” Reflect upon the various theories we have now that couldn’t be explained in the past without invoking the supernatural: The germ theory of disease, atomic theory, DNA and genetic theory, day and night, tides, seasons and gravity. Just because humans don’t understand something doesn’t mean it is right (or wrong!).

Controls in Science

Another major way that science is different from other ways of learning is the concept of controlled experiments. An experiment is typically designed to investigate the effect of changing one (or as few as possible) factor or as few as possible). Using the above example of flies, it would have been undesirable to compare meat exposed to air with meat that had been boiled and covered with fine cloth. If this were the experimental conditions, it would be impossible to identify whether it was the boiling or the fine cloth that prevented the formation of the flies. The comparison to the untreated meat is also important to ensure that the correct conditions were available for the formation of flies in the first place.

A short quiz will test your reading skills.
As an expert in the basic definitions of science, it is now up to you to apply these terms and DO some science. You are going to start with a hypothesis in this case, but a scientist can begin with any part of the scientific method. Many scientists jump into a field by trying to explore predictions of a theory, for example.

**THE PROBLEM:** Coins from the US Mint can circulate among the population for an average of 30 years. Have you ever paused to think of what happens to a coin during this time?

1. Your duty, in teams of 2, is to develop a hypothesis for why the mass of a penny might change while it is in circulation. It is also possible to have a “null hypothesis,” which means that no change will be seen.  
   *Record your hypothesis on the report sheet.*

2. Using your hypothesis, make a prediction for what will happen to the mass of a penny over time while in circulation. Specifically, address which (if either) penny would be heavier; a 2002 or a 1979.  
   *Record your prediction on the report sheet.*

3. Instead of a philosophical, logic argument, it is now time to collect data to test the hypothesis.
   a. What experiment(s) will test your hypothesis?
   b. What will be the predicted outcome of the experiment (based on answers above).
   c. How can you present the data? (weight vs. year of minting or weight vs. years in circulation)
   d. *Record your proposed experiment on the report sheet*

**BALANCE ETIQUETTE:** these are SENSITIVE instruments that you will use for the rest of the semester/year. Do not throw, drop, slam or grind objects in or on the balances.

4. Each group will weigh two or three sets of pennies from different years. Weigh the group of pennies and record the combined mass. Determine the average mass of a single penny from that set. Provide the average mass of each penny set to the instructor.

5. While waiting for the instructor demonstrations, briefly evaluate the classroom data. Do you need to perform additional experiments or to collect more data?

6. Observe the instructor demonstrations, and record your observations on the report sheet.

7. Interpret the results, based upon the classroom data of mass and year. Evaluate your hypothesis, prediction and experiments.
Penny Experiment Report Sheet

Name: _________________________ partner: ____________________________
Lab section ________________________

Use full, complete sentences that are grammatically correct. Review definitions of terms, make sure your answer fits the definition.

1. Hypothesis:

2. Prediction (include specific details):

3. Description of experiment, and predicted outcome

4. Data for pennies:

<table>
<thead>
<tr>
<th>Year(s)</th>
<th>Number of pennies in set</th>
<th>Mass of penny set</th>
<th>Average mass of penny</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(optional)

5. Evaluation of results. Was the data collected by the class consistent with the predicted outcome of your hypothesis? Was your hypothesis correct? Do you need more data, or need to conduct further experiments to determine any changes in the masses of the pennies?

6. Observations for instructor demonstrations.
7. Interpret the results, based upon the classroom data of mass and year. Make specific references to the data or observations to support your statements or conclusions.

Was your original hypothesis correct? Use the data to support your statements.

8. Using the data from this lab, can you develop a statement regarding the changes in the mass of pennies and years in circulation?

9. Describe how this activity has affected your impression or awareness of the scientific method.