Science, the Scientific Method, Controlled Experiments and Scientific Skills

Science:

Considering this is a science class, I think that is very important for us to ask an important question:

**WHAT IS SCIENCE?**

This can be a very complicated question, but we are going to give a very simple answer at first, and then dig deeper.

**Science is a collection of KNOWLEGE about the natural world and**

**the PROCESS used to get that knowledge.**

**Scientific knowledge MUST BE based upon**

**OBSERVATION, EVIDENCE and EXPERIMENTATION.**

So that is the simple answer.

Let’s look at some of the key characteristics of scientific thinking:

* Science is a way of thinking about and understanding the world around us.
* Science is using **observations** to form our ideas.
* Science is using **rational**, **evidence based** reasoning in order to draw conclusions.
* In order for an idea to considered science it must be verifiable with a **controlled** **scientific** **experiment** designed using the **scientific method**.
* The experiment must be **repeatable**.
* In order to be accepted as science an idea must be subjected to “peer review”. This means other, **independent** scientists must be allowed to test your ideas and to look for any mistakes or flaws.
* No idea (no matter how good) can be considered science without **data** collected in a controlled experiment to back it up.

What makes science so wonderful is that is self-correcting (through peer-review). Incorrect or incomplete ideas eventually fall apart under continued testing and experimentation. There are many examples of scientific ideas that have been proven incorrect (or incomplete) over time, a few examples are:

* The four element theory
* Early atomic models
* Miasma Theory
* Preformationism
* Caloric Theory
* Parts of Dalton’s atomic theory
* Geocentric Universe/Solar system
* Newtonian Mechanics
* Inheritance of acquired physical traits

\*When scientists develop or try to develop a new **Theory** they must follow a process known as the **Scientific Method**.

\*Only knowledge that has been found using the **scientific method** can become part of science.

\*The scientific method is used to help prevent incorrect theories from developing.

Scientific Skills

All scientists must make use of certain skills in order to do science. Some of those skills are:

* **observing (qualitative and quantitative)**
* **predicting**
* **classifying**
* **measuring**
* **estimating**
* **making and models**
* **making hypotheses**
* **designing and performing experiments**
* **organizing and displaying data**
* **graphing**

We make use of most of these skills nearly every day. We estimate the distance we need to walk *“ ...about 10 blocks.”*  or peoples heights *“ she’s 5 foot 10.”*. We classify things also: juniors and seniors, teachers and students, fruits and vegetables, plants and animals. We make measurements when we weigh ourselves or check our shoe size or check the speedometer in our cars. We continuously make observations: *“That smells funny”* or *“It’s cold outside”* or *“It’s 2oC outside”*. We use models very often. Any time you use Google Maps or draw a diagram you are modeling. All of the science skills are used in this way.

Theories vs. Natural Laws

A **natural law** (often just abbreviated to **law**) simply describes *what* happens. Natural laws can often be summarized by a mathematical statement.

A **theory** is a model that attempts to explain *why* or *how* something happens.

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
  + Has **never ben disproven** by scientific methods

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 be either modified to explain the new results or discarded completely.

If a theory fails to make accurate predictions, it is flawed. That doesn’t mean it is wrong and needs to be thrown out, just that it may need to be tweaked or added to. It might be wrong, but further testing is required.

Examples of Theories and Laws:

* The **Theory of Evolution by Natural Selection** not only states that species change over long periods of time, but also provides an explanation of how this occurs based on heredity, mutations and the idea of fitness. There has never been an experiment that has contradicted the ideas of natural selection, but thousands of experiments have confirmed it.
* The **Law of Gravity** states that objects attract other objects based on their masses and the distance between them. It is a law and not a theory because the Law of Gravity does not explain *why* masses attract each other.
* The **Law of Conservation of Energy** states that in any physical process, the total amount of energy present before and after the process is the same.
* **Kinetic Molecular Theory** is a theory that states all matter is made of molecules. The theory explains how the molecules move and explains properties of solids, liquids and gases. The theory also explains diffusion, thermal energy transfer by conduction and convection and many more.

**Questions:**

1. Why do you think that the fact that an experiment can be repeated is so important?

2. I **observe** a man walking with an umbrella. I **observe** that it is raining. I conclude that when this man opened his umbrella it caused the rain. I make a **hypothesis** that whenever anyone opens an umbrella it rains. Explain how we can use the scientific method to test my hypothesis.

3. Explain why in the “Flat-Earth” example above the scientist cannot conclude that “The Earth must be a sphere.”.

4. I **observe** that when more people are wearing sweaters it is colder outside. I **hypothesize** that as people put on sweaters it causes the Earth to cool. I make very detailed **measurements** of the number of people in sweaters and the temperature by getting a team of scientists to sit on busy corners in cities all over the world and count the number of people wearing sweaters and measure the temperature every day for one year. I collect all of the data and I analyze it. The measurements seem to confirm my hypothesis! The more people in sweaters, the lower the temperature. I am very excited as I **predict** that I can solve Global Warming and Climate Change by getting more and more people to put on sweaters! Explain the flaw in my reasoning.

5. Give 2 new examples (not given in the notes) of how things are classified in daily life.

6. Give an example of an observation that is not an estimate.

7. Explain the difference between an estimate and a measurement.

8. Give an example of a quantitative observation that does not require units.

9. Briefly describe the difference between a Natural Law and a Scientific Theory.