Chapter 1

What is Science, anyway?

The first time I used the CD in my oceanography class, I and the TA's were astonished by how difficult it was for our students to distinguish between observations and interpretations. As I wondered why this would be so, and engaged in a number of conversations with my colleagues, Prof. Greg Kelly (Education) and Prof. Charles Bazerman (English), I began to realize that in spite of my many years of successful research and writing about scientific investigations, the process of science was something I learned almost automatically through a long apprenticeship with my thesis advisor and subsequent interactions with my colleagues. I was so completely immersed in science thought that I was unable to effectively teach science as a process until I was exposed to others who thought about these matters and inspired me to reflect on my own methods and attitudes from a fresh viewpoint.

One misconception about science is that one is doing science when following the "scientific method". In fact, most scientists use the scientific method as a format for writing up their work and preparing proposals. Most often the "aha" experience results from inspiration born from intense discussions with colleagues or in quiet reflection. Science can be hard work. An apparently simple result may come after days, months, or even years of investigation.

Entire books have been written about what is, and what is not science, so I will most likely leave something out in this short discussion, but I continue anyway. Broadly defined, science is a process by which the scientific community reaches agreement about their area of interest. It specifies how observations are made and documented. It requires that experiments be reproducible by others. Experiments are usually motivated by a theory to be tested. A good theory will not only explain a wide variety of experimental results and will be able to predict the outcome of experiments not yet performed. The results of observations and their interpretations in relation to a theory are generally presented first in scientific meetings and workshops, where other scientists with expertise in the field can provide input. Then the results are carefully written about and published in scientific journals. Articles are generally reviewed for accuracy and clarity by 2 or more experts in the field. Through this process of documentation, duplication of results, and critical review, scientific results become part of the body of accepted science knowledge.

Theories are important in science. Anyone can make up a theory, but a good theory can withstand the test of observations and validation by others. A theory must explain a variety of phenomena. For example, a single theory that can explain major features on both North American and South American continents is much more powerful than two separate theories that must be created for each continent. The theory of plate tectonics was widely accepted because it could explain a lot of very puzzling observations and the major features of the earth's surface. Theories with wide acceptance can make predictions in areas where no data have been gathered. In fact, this is one of the ways that theories are tested. A prediction based on theory is made, then data are gathered to test the prediction.

Sometimes widely accepted theories are overturned. In Galileo's time, the rotation of the planets, sun, and stars around the earth was an accepted fact. Published writings did not need to refer to research proving this "fact". However, new astronomical data stimulated a rethinking of that "fact" and previous interpretations became discredited.

An important property of a scientific theory is that there is some possible evidence that could cause us to reject it. A theory that makes no observable predictions would be impossible to test, so wouldn't be particularly useful. This requirement, which is sometimes called "falsifiability", is commonly confused or ignored when religious belief conflicts with scientific theory, such as the origin of the earth and life on it. It is a person's right to choose to believe the literal biblical story of man's creation. This would fit in the category of "belief" or religion, rather than science, because the belief is based on unshakable faith rather than evidence. Morris states, in "Scientific Creationism", pp15-16, that "*there is not the slightest possibility that the facts of science can contradict the Bible and, therefore, there is no need to fear that a truly scientific comparison of any aspect of the two models of origins can ever yield a verdict in favor of evolution*". This kind of assertion does not allow an interpretation (of evidence) that would contradict the creation theory or favor an alternate theory, so would not be considered "scientific."

Science as an agreement among Scientists

Most basic science research today is funded by grants. Research requires laboratories with often expensive instruments, trips to meetings to present results, and salaries to support graduate students and technicians. A scientist will write a grant application that explains the purpose of the research, how it will add to the current knowledge, the proposed research methods, and a budget. There is not enough money to support all requests for funding, so competition is fierce. Each grant proposal is reviewed by several outside experts, then by a panel of scientists who meet to rank proposals based on their scientific merit and importance. An investigator with a sound reputation for quality research has a better chance of getting funding than one with a poor reputation. Distortion or falsification of research results is extremely rare, because scientists know that their colleagues are lurking in the background ready to criticize inferior methods and mis-interpreted data. The science community is extremely unforgiving of dishonesty.

Peer review is one of the cornerstones of the science enterprise. It occurs at all levels. It begins with obtaining grant funding, continues with the presentation of results at conferences and finally, in the publication of findings.

Science is a "way of knowing". It is based on the use of observations and evidence, critical review, and public discussion. Scientists agree, through this process, on credible methods of conducting experiments and what knowledge is accepted and what is questionable. Scientists use intuition, but must show that predictions based on their intuition are supported by evidence, which is then subjected to the rigors of peer review and publication.

Controversy in science

Many scientific theories are supported by strong evidence and are universally accepted. However, some fields of study are very complex and the available observations are insufficient to unambiguously distinguish between competing theories. In fact, nearly every theory begins this way, and scientists diligently attempt to find evidence in support of their preferred theory.

This may be a daunting task that takes years and extensive research to solve. Curing cancer is an example. Another is the study of the effect of different foods and vitamins on health, where conflicting claims and faulty "research" make it difficult for the public to separate the credible from the uncredible. Interest groups with a stake in the interpretation (e.g. timber companies vs environmentalists, commercial fishermen vs marine ecologists, etc.) will emphasize particular studies or experiments that support their viewpoint. When data are incomplete and the subject is complex, numerous interpretations of the data may be possible. Adding to the confusion, there always seems to be at least one renegade or contrary scientist to be interviewed by the media, even though there may be overwhelming agreement by mainstream researchers. This renegade may get equal exposure to those who explain the prevailing view. I still meet those who do not believe in the theory of plate tectonics. No wonder the public is sometimes confused by claims of "experts" who disagree!

Teaching Science Process

There are probably many ways of teaching science process, but I have arrived at a method that makes sense to me. I use the activities of practicing scientists as a model. Ultimately, I hope to meet my primary goal, which is to help my students become intelligent and critical consumers of science information. I hope that my students will be able to examine scientific claims for bias and expect that the Western Fuels Association will emphasize evidence supporting the view that global warming is not occurring (that it will be good for us, so go ahead and burn lots of fuel). I hope that my students will then look for viewpoints expressed by groups representing other constituencies, or by respected science societies like American Geophysical Union or the National Academy of Science. My star student will go deeper into the actual research results. I hope that he/she has enough basic math, science and reasoning skills to make a good analysis.