In Search Of . . . . Real Science

by Richard Filson

The Student Concept Of What Is Science When kids take their first science class in school, they think that every lab activity is an experiment. This notion is far from the truth. I maintain that an experiment is an investigation in which the experimenter attempts to test a hypothesis. We do lots of other things besides experiments such as demonstrations, replication exercises, and descriptive science. Descriptive labs and replications are all too common in textbooks. Descriptive science can be legitimate science so long as observations are made and relationships are inferred by the student. A major theme of biology, form and function is often taught this way.

Replication exercises usually short change the student by depriving them of the opportunity of discovery learning. This not real science. Rather than start by asking students a general question, a replication lab will follow a thorough textbook discussion of a phenomenon. Diffusion and osmosis are usually explained before students do the lab. The lab is simply replicated to illustrate the process or to reinforce understanding. This is tell and show. Students have the answer they think you want them to know. Where is the scientific thinking?

Real Science Is . . . Real science for our students is when they are thinking scientifically. What all real scientists do is a special brand of critical thinking. Like all critical thinking, there must be a purpose for thinking. That for scientists is generally "I want to know how or why something works in a particular way. Or what relationship exist between two things?" What distinguishes scientific thinking from other forms of critical thinking is how we refine our questions and develop the concept we are working with. What this involves is a hypothesis. A guess about how or why something works in a particular way. And for those of us who experiment, this involves a test of our hypothesis.

Demonstrations can be effective if they challenge a student's preconceived concept. This can be accomplished by using an inquiry approach. Start with an observation and follow with a question. Require students to develop a hypothesis then design an experiment to test it. For diffusion, set up a molasses cell in water and ask students to hypothesize why the liquid rises in the vertical tube.

Overcoming the Weakness in the Science Curricula The weakness in the science curriculum that creates a barrier for students to think clearly and scientifically is stating the hypothesis. In this forum I will . . .

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- demonstrate how hypotheses are an essential part of science methodology.
- demonstrate formatting hypotheses that will teach students how to focus on the important parts of a scientific problem and learn to make appropriate predictions and relevant conclusions

We have all read and heard that good science teaching emphasizes process skills or higher order thinking skills. These process skills are implicit in the "scientific method". Science dogma describes the method as a series of steps such as stating the problem, observing, hypothesizing, experimenting, collecting data and so on. The one part of the scientific method that is the least apparent and seldom explained adequately is hypothesizing. Although it is commonly accepted that students should know the scientific method, few students can get beyond the hypothesis.

Why is this? I believe that students have difficulty with hypotheses because their books and lessons mention hypotheses, but almost never really explain or model them. And frequently hypotheses are confused with theories. A good many teachers use the terms theory and hypothesis interchangeably. No wonder our students are confused. From the California Science Framework: "hypothesis--a proposition assumed as a basis for reasoning and oftensubjected to testingfor its validity." Also from the framework, "theory--an explanation or model based on observation, experimentation, and reasoning, especially one that has been tested and confirmed as a general principle helping to explain and predict natural phenomena."

I look at a hypothesis as a proposed relationship to be tested, a concept in need of validation. On the other hand, a theory seems to be broader. For example Redi tested the hypothesis that maggots on decaying meat come from flies rather than from the meat. The theory of biogenesis states that living things come from living things, like produces like. This theory was the outcome of many experiments and observations including scientists such as Redi, Spallazani, and Pasteur. Students need guidance in understanding the difference between these two terms.

Why Do Students Need to Know How to Hypothesize? Biology students need to know how to hypothesize simply because the hypothesis is the core of experimentation which in turn is the ultimate opportunity to utilize critical thinking as a scientist. Of course, students need to develop the cognitive skills involved in descriptive biology and the manipulative skills using laboratory equipment. However, cognitive skills and manipulative skills alone can not explain the natural world. These important activities do prepare students for the time when real experiments will be performed. It is during what I call "experimental biology" that critical thinking skills like hypothesizing, interpreting data, and making inferences can be best developed.

Experimental biology is the ideal place to teach the scientific method. Students can formulate and test hypotheses. They can manipulate and control variables and observe outcomes of events for which they don't already know the answer. However, this only works well when the student recognizes a possible relationship to be tested. Being able to hypothesize allows the student to focus on the specifics of a relationship. It limits the focus to just two things at a time, the independent and dependent variables. Furthermore, using some formats, a hypothesis allows the student to predict what will happen to the dependent variable when the independent variable is manipulated. It is in this situation we can improve clarity of thinking and utilize the scientific method to the fullest extent. Furthermore, students who usually miss the target when stating conclusions can be effectively guided to logical conclusions when conclusions are linked to the hypothesis. Experimental biology is the perfect place for hypotheses. It is the perfect place to teach students the process of science, to experience "real" science.

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