

[Although this article is about biology, the excerpts below are useful for ALL sciences -- and for high school. -- Jane J]

What Kinds of Scientific Concepts Exist? Concept Construction and Intellectual Development in College Biology

by Anton E. Lawson et al, Arizona State University.

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[Excerpts follow.]

At the most direct level, meaning can be derived from immediately sensed input giving rise to color concepts such as green/red/blue, external state concepts such as hot/cold, sharp/dull, and internal state concepts such as hunger, thirst, and tiredness. Here complete meanings are immediately apprehended from the internal or external environment. Thus, a first category called CONCEPTS BY APPREHENSION can be identified.

... objects such as tables, chairs, and events such as running and resting, and relations such as taller and heavier are mental constructions. Yet we lose sight of this fact because we have gathered so much evidence to support their postulated existence. Hence, a second class called DESCRIPTIVE CONCEPTS can be identified. To understand descriptive concepts, one must mentally construct order from environmental encounters. In short, descriptive concepts allow us to order and describe experience.

HYPOTHETICAL CONCEPTS are defined as those that, in theory, could derive meaning from observation if it were possible for one to extend the time frame over which the necessary observations are made. However, in practice, such observations are either not possible or very unlikely, and meaning must be derived from one's ability to imagine past or future events and situations. Thus, hypothetical concepts have intermediate difficulty in terms of knowledge acquisition and understanding. [Jane's note: in this paper, Dr. Lawson introduces hypothetical concepts, and justifies their existence.]

The third type of concept described by Lawson et al. is also produced by postulation and test. However, this type differs from descriptive concepts in that defining attributes are only indirectly testable. The primary use of these concepts is to function as explanations for events that need causes, but for which no causal agent can be perceived. Angels and ghosts fall into this category. Common examples from science are photons, electrons, atoms, molecules, and genes. These are called THEORETICAL CONCEPTS. The reason for the existence of theoretical concepts can be found in a basic assumption that humans make about their world: events do not occur without causes. Thus, if we perceive an event, but cannot perceive objects or processes that caused the event, we do not conclude that the event is spontaneous and without cause. Instead, using analogical reasoning, we invent unseen objects and interactions to explain the event in perceptible causal terms. Because theoretical concepts are imagined and function to explain the otherwise unexplainable, they can be given whatever properties are necessary in terms of the

theory of which they are a part. That is, they derive meaning from the analogies upon which they are based and from the postulates of specific theories in which they reside

According to developmental theory, descriptive and theoretical concept construction is linked to intellectual development because the process depends in part on procedural or 'operational' knowledge structures (i.e., reasoning patterns) as well as prior declarative knowledge structures. Development of procedural structures occurs gradually with age because it depends not only on maturation but also on experience (both social and physical) and on the individual's self-regulatory mechanisms. Thus, **during intellectual development, concepts by apprehension come first. Then descriptive concepts are constructed during childhood followed by the construction of theoretical concepts during adolescence and adulthood. Similarly, when an adult begins to construct concepts in a new field of study, the descriptive conceptual foundation must at least be partially in place before theoretical concepts are constructed. ...**

This theory of concept construction and intellectual development leads to the prediction that students at any one age who vary in the extent to which they have developed procedural knowledge structures (reasoning patterns) should vary in the extent to which they can profit from science instruction aimed at teaching descriptive and theoretical concepts. This prediction has been confirmed by several previous studies ...

Note that the present theory implies that in any field of investigation, the descriptive foundation should precede the introduction and testing of alternative theoretical explanations. However, it does not imply that all questions of causality should be avoided until students have developed higher-order reasoning patterns. Rather, the view is that **it is the process of generating and testing alternative theoretical possibilities that leads to the development of higher-order thinking.** Unfortunately, the introduction of theoretical concepts is usually not done in this way. Instead, most textbooks introduce them as "facts" and seldom bother to introduce the alternatives, the arguments, and the evidence used by past scientists to arrive at such "facts". Thus students are not provided opportunities to develop higher-order reasoning skills, and they also are not provided opportunities to develop understanding of how science works.

...

CONCLUSIONS AND EDUCATIONAL IMPLICATIONS:

... Because many, if not most, of the concepts that fill the syllabi of college science courses are of the hypothetical and theoretical nature, the implication seems clear. College science instructors should not only concern themselves with introducing new terms/concepts. They should also concern themselves with student thinking abilities, that is, with students' continued intellectual development.

To do this, a careful analysis of the kinds of concepts introduced, as well as the order and means of their introduction should become matters of concern. In introductory biology courses this means overturning the widespread and long-standing tradition of starting courses with the theoretical concepts associated with chemistry (e.g., atomic and molecular structures) before progressing to the more descriptive and hypothetical concepts associated with whole organisms.

Clearly, a **reconfigured introductory biology course that starts with descriptive concepts and progresses to hypothetical concepts, and then to theoretical concepts, seems in order.** Such changes may not only help students better understand concepts and promote their intellectual development; they might also help solve the widespread problem of college student attrition from the sciences....