Iowa Science Teachers Journal

Volume 30 | Number 1 Article 3

1993

Teaching the Nature of Science

Gerald R. Walsh
Washington Junior High School

TEACHING THE NATURE OF SCIENCE

Gerald R. Walsh
Washington Junior High School
51 North Grandview
Dubuque, Iowa 52001

Early in my teaching career, I came to the conclusion that my colleagues did not approach science in the same manner as language arts, social studies or math teachers approached their subjects. While we were trying to "stuff" our students with all kinds of information of a specific nature, they focused upon producing a general literacy. They did not presume the majority of their students would one day become authors, mathematicians or social workers; instead they assumed that all students required communication skills within their respective subjects. Their mission seemed to be the promotion of literacy within the framework of their respective disciplines.

Science teachers should consider adopting a similar philosophy and get on with the business of teaching kids what science is and why it is important in their lives. Experts suggest (Abimbola, 1983) that a science curriculum should include information of how scientific knowledge is established, how that knowledge becomes valid and how it may eventually change its form and meaning; information that strikes me as being more practical than learning the strokes of a four-cycle engine or memorizing the valences of the transition metals.

Students in some of today's classrooms are required to recall trivia that fails to provide a modicum of scientific understanding. Some teachers expect students to memorize parts of the periodic table, detailed flow diagrams of the citric acid cycle or all the bones and muscle attachments of the human body. I believe students would reap greater benefits by focusing upon a general understanding of the nature and meaning of science instead of resorting to tactics of pedagogical drudgery.

In addition to general content, students need to know the scope and limitation of science. They need to learn about science as process, history and cultural integration. This information should be incorporated into every science class and progress in complexity and abstraction. In this manner the various subdisciplines of science would appear more integrated, producing greater literacy as a by-product. The following topics might serve as examples:

Science isn't the only source of knowledge.

Some people claim that scientific knowledge represents the pinnacle of truth, or is the supreme method of determining "truth." This notion seems to be predicated upon a myth of absolute objectivity that science and scientists appear to possess. Students should examine the "objectivity" of the scientific process in a more critical light. Proponents of science need to know that behind all hypotheses and observations lies a natural prejudice which is determined by the structures, paradigms and theories of the observer (Hodson, 1988) (Flannery, 1988). Absolute objectivity cannot be achieved under any circumstance, including science.

There are also assumptions and "truths" which are emotionally or spiritually rooted in individual experience and, as such, exist outside the parameters of scientific investigation. It is not possible to reduce the work of an artist to a scientific statement. Even the language mode of the artist differs from that of the scientist. When communicating, the scientist seeks a precision that attempts to reduce subjective individual interpretation, while the ambiguous and sensual language of the poet remains a vital component of human expression. Our lives and society are enriched by both.

Science is limited to what it can investigate.

Recognizing the nature of its objectivity, science is bound by a prerequisite to limit its investigations to areas that produce a "universal consensus" (Campbell, 1921). Agreement among scientists is essential and is probably the most obvious distinction between science and the arts, or religion.

As the body of scientific knowledge expands, collisions with other belief systems will inevitably occur. When that happens science sometimes appears to engage in a form of "religion bashing." Whether conflict centers around a Ptolemaic model of the universe or evolution as a better explanation of the diversity of living organisms, certain groups of people have taken and will continue to take offense. The concept of "universal consensus" may limit scientific investigations, but it also puts the burden of proof upon those who disagree with its conclusions. Scientific knowledge need not result in apostasy.

A theory is not a hunch.

Science is based upon working theories that are used to test and predict hypotheses. A scientific theory is neither a hunch nor a guess, but rather an interconnected framework of ideas. It is a potential explanation based on available evidence.

A scientific law is not just a theory that has stood the test of time and undergone a promotion. A scientific law states a relationship between concepts such as density's connection between mass and volume or the proportionality relation between volume and the temperature of an enclosed gas when the pressure is held constant.

Perhaps the most common ploy utilized by proponents of a particular pseudoscience is to prey upon the public's misunderstanding of the term "theory." Dealing with this problem of definition during science class seems infinitely more practical than public debates concerning the credibility of "creationism" as a viable alternative to evolution.

The retrieval of scientific information.

Facts are relatively important if they can be linked into concepts or laws. Laws make sense when connected by theory. In an age when information is generated at geometric proportions, we need to be managers and retrievers of data. This task is made easier in science because general information is valued more than specific.

Teachers furnish an important learning strategy by providing students with this means of knowledge assessment. By keying students into an informational hierarchy, bulky texts can be made more manageable, student stress levels will be reduced during exams and important insights may be gained concerning the philosophy of science.

Scientific explanations must be testable.

Karl Popper (Popper, 1968) posited the idea that information is not scientific unless a means of proving it false can be devised. Knowledge dealing with "falsifiability" is useful in discerning science from pseudoscience. A scientific theory must be a tightrope subject to constant scrutiny through testing lest it devolve into dogma. Any statement that cannot be held accountable through testing is nonscientific. When a creationist asserts that the fossil record and subsequent tests of its authenticity are the workings of God or the Devil (depending upon the source) and meant to trick us, the notion violates the criterion of falsifiability.

Absolute certainty is absolutely uncertain.

The quest for "truth" is never ending. Scientific theories gain acceptance because evidence accumulates to support them, not because dogmatic assertions promote reality (Siegel, 1978). Newton's Theory of Gravitation was replaced by Einstein's because it could explain more. Newton's explanation was not so much wrong as it was limited or incomplete. Einstein's explanation is further up the previously mentioned hierarchy due to its generality, thus making it more powerful at generating laws.

Uncertainty does not contradict "universal agreement." A scientist recognizes that absolute truth shall always remain beyond the grasp. Scientific agreement comes from theory verification. The theory is accepted until it can no longer fulfill that function. However, the theory's replacement must explain the old, in addition to the new, thus preserving universal agreement.

In addition to the above examples, the following questions serve as additional possibilities for exploration and class discussion:

1. Does the discipline of science distort reality by objectifying and abstracting experience?
2. Is science a continuation or departure from common sense?
3. Can laws exist independent of theories?
4. Is meaning a consequence of one's paradigm?
5. Does science progress in an orderly, rational and cumulative fashion?
6. Is there an interplay between scientific and social paradigms?

If the nature of science were made a component of all science course work, a more coherent understanding of science would result, thus preparing non-science students to function as part of a literate citizenry and giving science majors a greater understanding of the inner workings of their chosen field.

The short bibliography following this article identifies of some favorite sources pertaining to the philosophy of science. I've attempted to select books or articles accessible to the general public and to share with you my criteria for selection.

Suggested Resources

Pirsig, Robert M. 1974. *Zen and the art of motorcycle maintenance*. New York: William Morrow & Co.

In the days past when I was a lingering hippy, "Zen" was given to me by a friend. The book generated an enthusiasm for the nature of science that continues. It should be read and reread.

Bronoski, J. 1965. *Science and human values*. New York: Harper Row.

If I could assign one book as required reading for people who are mistrustful of science, this would be it. It's a remarkable little book written by a remarkable man. It purports to show that science is a creative endeavor and that scientists are typically creative caring individuals.

Bronoski, J. 1973. *The ascent of man*. Boston: Little, Brown and Co.

Based upon the television production of the same title, this book traces the evolution of our culture from the perspective of scientific and technological advances. A substantial segment of society was turned on to science through Bronoski's efforts.

Pine, Ronald C. 1989. *Science and the human prospect*. Belmont, CA: Wadsworth Publishing Co.

My son brought this book home from Wartburg College where it is a graduation requirement. It is easy to read, informative and functions as an introductory course to the nature of science. I wish more colleges had a similar requirement. It also contains a great bibliography.

Jean, James (Sir). 1981. *Physics and philosophy*. New York: Dover Publications, Inc.

Jean's book at times becomes rather technical, but getting through it is worth the effort. It serves as a good introduction to the Quantum Theory and traces the importance of the development of nuclear physics from a philosophical point of view.

McCain, Garvin, and Erwin M. Segal. 1988. *The game of science*. Pacific Grove, CA: Brooks/Cole Publishing Co.
This book does a thorough job of listing the "rules of the game" and exploring several types of pseudosciences from the perspective of those rules.

Spellberg, Nathan, and Bryon D. Anderson. 1987. *Seven ideas that shook the universe*. New York: John Wiley & Sons, Inc.
Explores the notion of paradigm changes and their cultural impact.

Koestler, Arthur. 1959. *The sleepwalkers*. New York: MacMillan Co.
If you are not interested in Copernicus, Kepler and Galileo, read it for the epilogue alone; it does a superior job of presenting the nature of science in very few easy-to-read pages.

Gilkey, Langdon. 1985. *Creationism on trial*. San Francisco: Harper & Row.
This notable book is written by a theologian who testified against "scientific creationism" at the Little Rock trial. It offers an insightful comparison between science and religion.

Davies, Paul. 1983. *God and the new physics*. New York: Simon & Schuster Publishers.
Mr. Davies' book gives a detailed and fascinating description of Quanta Theory and Relativity at the interface of science and metaphysics. I had to read many passages more than once; but for the most part, it is not too "heavy."

Kuhn, Thomas S. 1970. *The structure of scientific revolutions*. Chicago: University of Chicago Press.
The book cover says it all: "A landmark in intellectual history." Kuhn's book is a masterwork in the annals of science history and philosophy. It also functions as a vehicle for developing understanding and tolerance of contrary ideas. I believe this is a "must read" for science educators.

References

Abimbola, Isaac O. 1983. The relevance of the "new" philosophy of science curriculum. *School Science and Mathematics.* 83(3, March).

Campbell, Nortman. 1921. *What is science?* Dover Publications.

Duschl, Richard A. 1985. Science education and philosophy of science twenty-five years of mutually exclusive development. *School Science and Mathematics.* 85(7, November).

Flannery, Maura. 1988. What is science? *The American Biology Teacher.* 50(6, September).

Hodson, Derek. 1988. Toward a philosophically more valid science curriculum. *Science Education.* 72(1).

Popper, Karl R. 1968. *Science: Conjectures and refutations: The growth of scientific knowledge.* Harper & Row.

Siegel, Harvey. 1978. Kuhn and Schwab on science texts and the goals of science education. *Educational Theory.*