The Nature of Science & PERCEPTUAL FRAMEWORKS

Emphasizing a more balanced approach to science instruction

Erica Michaels and Randy L. Bell

In today's climate of content standards and high-stakes testing, science teachers are under more pressure than ever to focus on the "ready-made" knowledge of science content. Yet, science educators have long advocated a more balanced approach to science instruction, including emphasis on the processes by which scientific knowledge is produced, as well as the characteristics of this knowledge. Unfortunately, the values and assumptions that go hand-in-hand with the production of scientific knowledge are seldom addressed in the classroom. Failing to address this "hidden" nature of science can result in serious misconceptions on the part of students regarding the strengths and weaknesses of the knowledge that science produces.

For example, the notion that the goal of science is to "prove" conjectures in an absolute sense is a common misconception of students. Closely associated with this misconception is the mistaken idea that scientific laws result from theories proven over time to be absolutely true. Current views of scientific knowledge recognize that there is always the chance (though sometimes remote) that new evidence or ways of interpreting existing evidence can result in changes in even the most cherished theories and laws.

Besides painting an inaccurate view of science, the misconception of science as "proven" knowledge can lead students to reject acceptable scientific ideas when the experts disagree. After all, if the knowledge were accurate, wouldn't all scientists agree? This question is asked either out loud or in the minds of students, in countless classrooms across the United States. Whenever controversial topics are addressed, including evolution, global warming, or the age of Earth, students interpret scientists' opposing ideas through their absolute views of science, too often rejecting good science as bad.

One answer to this conundrum is to address the tentative nature of science in the classroom. By showing that even careful scientists' observations and inferences are affected by cultural and social influences, teachers can help students understand that different viewpoints and controversy are to be expected, especially in the frontier realms of science. The *National Science Education Standards (NSES)* addresses these issues directly, calling for science instruction that includes such concepts as:

- Scientists are influenced by social, cultural, and personal beliefs (NRC 1996, p. 201);
- All scientific knowledge is subject to change as new evidence becomes available (NRC 1996, p. 201); and
- The work of science is a human endeavor that relies on certain qualities such as reasoning, insight, energy, skill, and creativity (NRC 1996, p. 201).

Making educated decisions

Studying the nature of science is not purely an academic issue. The ultimate goal for educators is to enable students as citizens of the world to make educated decisions in areas that require scientific knowledge. The *NSES* state, "Everyone needs to use scientific information to make choices that arise every day. Everyone needs to be able to engage intelligently in public discourse and debate about important issues that involve science and technology" (NRC 1996, p. 1). Similarly, in today's workforce it is becoming more important to have the advanced critical-thinking skills fostered through understanding science, scientific processes, and inquiry. Understanding the tentative and sometimes subjective nature of science will help students make sense of socio-scientific issues they will encounter.

For example, students who believe that all good scientific knowledge is objective might proceed differently with their decision-making than students who understand that scientific knowledge possesses subjective qualities and may be revised with new knowledge. What will be their conclusion when scientists disagree on the effects of global warming on our planet (or whether such a phenomenon really does exist), or when the latest scientific news indicates certain dietary choices are healthy one month, and hazardous the next? In such cases, students may put off important decisions because no absolute proof exists, or worse, they may fall into a trap of discrediting scientific work.

In addition to the myth that scientists are always objective, many students hold to other myths about the scientific enterprise (McComas 1996). These myths include beliefs that experiments are the only reliable route to scientific knowledge, careful evidence gathering will result in certainty, and science is procedural more than creative. Students may also believe that all scientists follow one general scientific method and this method provides absolute proof. With such a cut-and-dry conception of science that leaves little room for the human elements of creativity and intuition, many students find it uninteresting or difficult.

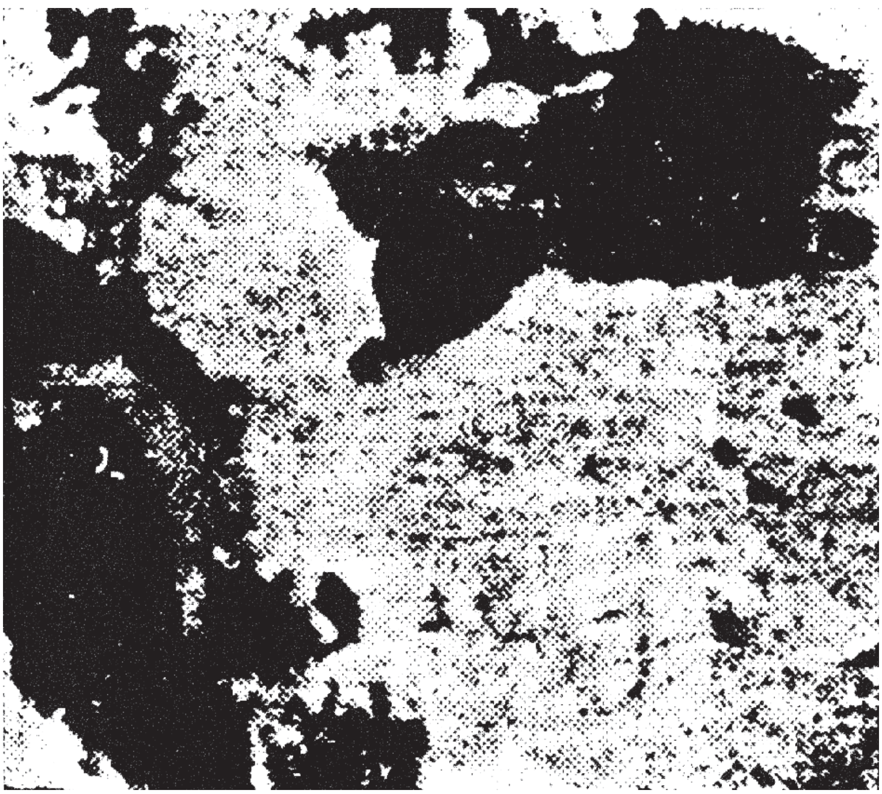
The only way for teachers to address these myths in the classroom is through changing students' conceptual understandings about the nature of science. For example, teachers can consider the "objectivity" of observations. Most everyone has heard that "seeing is believing." However, most are unaware that personal perceptions influence observations, as well as conclusions drawn from them. A practical way to demonstrate this concept to students is by presenting "gestalt images" that require an obvious framework for interpretation.

To begin, students look at Figure 1. The teacher then asks students "Do you see an image in the picture?" After looking again at the picture, students should consider that Figure 1 depicts a cow. If students still cannot see the image, Figure 2 (p. 38) provides an outline of the "hidden" image. Students will find that once they have seen the outline of the figure, it will be difficult to look at the picture and not see the image. Yet, without this framework, chances are they were unable to see a distinguishable image. The picture ("data") has not changed, but now students have a framework with which to interpret the data. Without the framework, students could not make sense of the data.

Figure 3 (p. 38) presents another image that can be interpreted differently based on one's framework. Students may see either a profile of a young girl wearing a necklace or a picture of an old woman, with a prominent nose and one eye in full view. The teacher can ask students "From a scientific perspective, if the 'data' in this problem is the drawing itself, what is the correct conclusion to draw from the data, the old woman or the young girl?" The data are the same for everyone, but the inter-

FIGURE 1

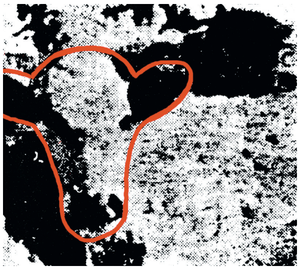
Grainy cow image.



ADAPTED FROM DALLENBACH (1951)

FIGURE 2

Outline of the cow.



pretation of the data depends on the students' perceptual frameworks. Students will see the girl or the old woman, but cannot see both at the same time (Lederman, Abd-El-Khalick, and Bell 2000).

Subjectivity of science

Understanding the nature of science in this context will help students to appreciate that one strength of science lies in its subjectivity. Science is a human endeavor, subject to the influence of social, cultural, and personal frameworks, yet the creativity and varied perspectives brought to science enable breakthroughs to occur and scientific progress to march on.

A good historical example of this is the case of Nicolas Copernicus and his heliocentric model of the universe. Copernicus did not support his ideas solely with the astronomical data of his time. In fact, his data did not differ dramatically from the data Ptolemy used to develop the geocentric model of the universe (Kuhn 1970). Copernicus's conclusions came as a result of a personal dissonance he felt with the systematic way astronomers needed to modify Ptolemy's theory. This dissonance provided the motivation for the development of a new way of looking at the universe.

Although the Copernican system was simpler than the Ptolemaic system, it was not more scientifically accurate. The heliocentric model provided a more aesthetically pleasing view, but acceptance of it was gradual because it required a major conceptual change in the way people thought about the universe and man's place in it. The framework of a geocentric universe was intricately weaved into the science, religion, and overall worldview of society. Heliocentricism had far reaching implications for the culture of the time and its gradual acceptance resulted in an overall paradigm shift in people's perceptions of man's place in the universe. Once this shift occurred, the framework that scientists brought to new astronomical questions was forever changed.

Another moment in astronomical history that required a change in scientists' personal frameworks was the nature of planet Saturn. Astronomical observations of Saturn in the sixteenth and early seventeenth century (Figure 4) prompted various ideas about what was occurring. Galileo, having recently discovered satellites of Jupiter, was therefore predisposed to seeing them again in his observations of Saturn, concluding that the "ears" he observed were also satellites. Two years later when the "satellites" disappeared, he wondered to his colleagues if his eyes had deceived him (Sheehan 1988).

Galileo as well as other astronomers who observed Saturn were not making errors in their observations; they simply did not have the frame of reference to interpret what they saw, much like students might have experienced in deciphering the picture in Figure 1 (p. 37). The idea of rings around a planet was completely new; astronomers had no prior experience to support this concept (Sheehan 1988). Determining what they were seeing required an intellectual leap of insight and creativity similar to the leap required to interpret the picture in Figure 1 (p. 37).

Christiaan Huygens achieved a breakthrough in perception when he concluded that Saturn is surrounded by a "thin, flat ring, nowhere touching" the planet (1659, p. 47). Similar to Copernicus' situation, Huygens did not have better data than his peers or predecessors, nor did he have a better telescope. In fact, his telescope was quite simple (Sheehan 1988). His diagram in *Systema Saturnium* (Figure 5) illustrates the product of his creative intuition—a model of Saturn with rings that explains the different appearances of the planet as viewed from Earth. Once Huygens presented the idea that Saturn was a planet with rings, an improved framework for what planets can look like was estab-

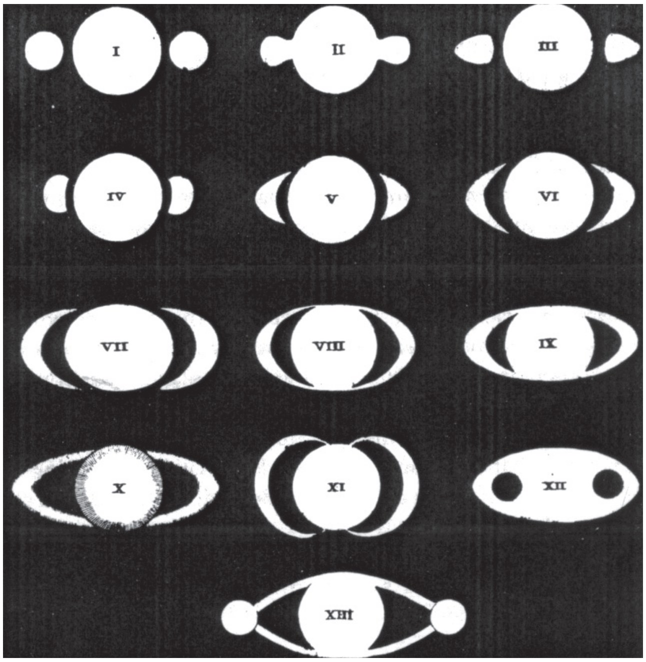
FIGURE 3

Old or young woman?

PERLS, HEFFERLINE, AND GOODMAN (1951)

FIGURE 4

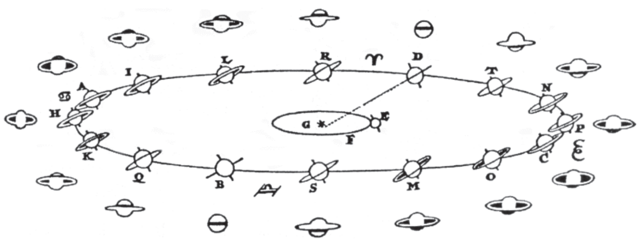
Early telescopic views of Saturn.



HUYGENS (1659)

FIGURE 5

Huygens' diagram of Saturn.



HUYGENS (1659)

lished. From then on, everyone who observed Saturn saw the rings (just as students will always see a cow when they look back at Figure 1, p. 37).

As in the case of the geocentric Earth, the rings of Saturn, and throughout scientific history, the synthesis of observations often includes considering past observations of others. Unfortunately, if an erroneous perception is introduced and then subsequently copied, misconceptions may continue for some time (Sheehan 1988). The same can be true for students in terms of how they have come to perceive science based on the personal frameworks they have developed over time, or on their cultural upbringing.

Cobern and Loving (2001) describe the importance of recognizing different multicultural approaches to describing natural phenomena in the science classroom and using these differences to help characterize science as it is understood by consensus in the scientific community. Multicultural perspectives can be brought into the science classroom by including more open-ended activities where there is no single "correct" answer. As a result, students can describe, compare, and reflect upon other perspectives and come to recognize that there can be more than one way to look at nature. As teachers we can provide opportunities for students to become aware of their own perceptual frameworks about the world and about science by illustrating the power these frameworks have on their conceptual understandings, and how changing frameworks can have a dramatic effect on how they view the world.

Furthermore, as students begin to see that perceptual frameworks are changed by breakthroughs in intuition and creativity, they will begin to understand science as a dynamic human endeavor. Ultimately, the goal is for students to view differing perspectives as the very strength of science rather than a fault, for then they can recognize the importance of their own perspective as they use science to explore their world. ■

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References

Cobern, W.W., and C.C. Loving. 2001. Defining "science" in a multicultural world: Implications for science education. *Science Education* 85(1): 50–67.

Dallenbach, K.M. 1951 A picture puzzle with a new principle of concealment. *American Journal of Psychology* 64:431–433.

Huygens, C. 1659. *Systema Saturnium.*

Kuhn, T.S. 1970. *The Structure of Scientific Revolutions*. Chicago: University of Chicago Press.

Lederman, N.G., F. Abd-El-Khalick, and R.L. Bell. 2000. If we want to talk the talk we must also walk the walk: The nature of science, professional development, and educational reform. In *Issues in Science Education: Professional Development Planning and Design,* eds. J. Rhoton and P.S. Bowers, p. 25–42. Arlington, Va.: National Science Teachers Association.

McComas, W.F. 1996. Ten myths of science: Re-examining what we think we know about the nature of science. *School Science and Mathematics* 96(1): 10–16.

National Research Council (NRC). 1996. *National Science Education Standards*. Washington, D.C.: National Academy Press.

Perls, F., R.F. Hefferline, and P. Goodman. 1951. *Gestalt Therapy*. New York: Julian.

Sheehan, W. 1988. *Planets and Perception: Telescopic Views and Interpretations 1609-1909*. Tucson: University of Arizona Press.