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Fundamental Skills in Science: Observation. ERIC Digest.

"We value our sight above almost everything else. The reason for this is that of all the senses sight makes knowledge most possible for us and shows us the many differences between things." Aristotle, "Metaphysics", Book I

"You see but you do not observe." Sherlock Holmes to Dr. Watson in "A scandal in Bohemia"

Long before our ancestors invented writing, they created art representing their observations, and detailed observations of the night sky were being systematically recorded nearly 3,000 years ago (Kavassalis, 2000). Though the early Greeks recognized the importance of our senses in constructing knowledge, the primacy of observations was formally put to the test by Galileo who faced charges of heresy for supporting the heliocentric theory of the universe. Risking his life for the sake of ideas, Galileo not only believed in what he observed through the newly invented telescope, he believed in the newly emerging views of scientific knowledge based on reasoning and observations.

De Duve (2002) has characterized science as being "based on observation and experiment, guided by reason" (p. 285), and this combination is what distinguishes science from other paths to knowledge. Derry (1999) makes the same point by saying that "well constructed scientific arguments, defending a scientific conclusion, generally rests on two foundations: reliable empirical evidence and sound logical reasoning" (p. 89). Martin (1972) was more explicit:

"Scientific theories are primarily tested against observation and accepted, rejected, or modified mainly because of observational data. Observation is thus generally considered to be the touchstone of objectivity in science; it seems to be primarily observation that provides an independent standard for the evaluation of theories and hypotheses. If it were not for observation, there would be little reason for choosing between scientific theories and fictional accounts, between science and pseudoscience, between warranted assertions and fanciful hopes. "

He goes on to caution, though, that "observation clearly cannot be maintained as infallible or certain. The existence of perceptual illusion, hallucinations, and other less dramatic perceptual errors proves that people can be deceived by their senses" (pp. 112-113).

Despite the apparent centrality of observation to the development of scientific knowledge, there has long been a debate about the exact role of observation and its supposed contribution to objectivity in science. It is acknowledged that observations can be both unreliable and theory-dependent (Hodson, 1986). Martin (1972) has made the argument "that a trained observer with certain knowledge and training can observe things that a person without this knowledge and training cannot observe." Further, "a person's background will influence what properties he [or she] visually attends to in a particular object, or indeed whether he [or she] attends to any properties of the object at all. Finally, the theoretical background of a scientist leads him [or her] to observe noncognitively objects which the layman, because of his [or her] lack of theoretical background does not observe at all" (p. 107).

Ironically, observations are seemingly at the heart of both stability and change in scientific understanding. Writers associated with Project 2061 (AAAS, 1989) stated that "sooner or later, the validity of scientific claims is settled by referring to observations of phenomena. Hence, scientists concentrate on getting accurate data. Such evidence is obtained by observations and measurements taken in situations that range from natural settings...to completely contrived ones (such as in the laboratory). To make their observations, scientists use their own senses, instruments...that enhance those senses, and instruments that tap characteristics quite different from what humans can sense (such as magnetic fields...Because of this reliance on evidence, great value is placed on the development of better instruments and techniques of observation, and the findings of any one investigator or group are usually checked by others" (pp. 26-27).

Shermer (1997) identified observation as accounting for the difference between science and pseudoscience and being the means by which scientific knowledge changes over time. He claims "science is different from pseudoscience...not only in evidence and plausibility, but in how [it changes]. Science [is] cumulative and progressive in that [it continues] to improve and refine knowledge of our world...based on new observations and interpretations" (p. 38). Derry (1999) points out that science needs better observations and more precise measurements for progress in understanding to occur.

Though human senses are limited in range and are easily deceived, observation remains at the heart of science and is the final arbiter in constructing and testing scientific ideas. Observation in science is more than "seeing"; it refers to skills associated with collecting data using all the senses, as well as instruments that extend beyond the reach of our senses, and it is influenced by the assumptions and theoretical knowledge of the observer.

OBSERVATION IN SCIENCE CLASSROOMS

For over three decades a focus on "science process skills", including the skill of observation, has been highly promoted in school science. Indeed, one influential elementary curriculum developed during the science curriculum reform flurry of the 1960s-"Science: A Process Approach"--was organized around the development of skills (AAAS, 1975). More recently, curriculum standards in science related to observation have typically appeared in sections related to learning through inquiry. According to the National Research Council (NRC,1996), students in the earliest grades should be expected to use simple tools--magnifiers, thermometers, and rulers--to gather data and learn what constitutes evidence (pp.122-123). Strategies for helping young students make detailed observations have been described (i.e., Checkovich & Sterling, 2001),

and ways of linking observations to familiar readings have been offered (i.e., Angus,1996).
Students in the middle grades should learn to conduct systematic observations, interpret data, use computers to collect and display evidence, and base explanations on observations (NRC, 1996; p. 145). In high school, students are expected to design and conduct investigations that involve the use of equipment and procedures to collect data, the use of computers to analyze data, and the development of models or explanations based on the evidence from investigations (p. 175). As an example of how to engage students in constructing a model from data, Cummins, Ritger, and Myers (1992) described an activity using observational data of the moon to construct a model of the sun-earth-moon system. More generally, "everyone should acquire the ability to handle common materials and tools...for making careful observations, and for handling information. These include being able to do the following" (AAAS, 1989):

* Keep a notebook that accurately describes observations made, that carefully distinguishes actual observations from ideas and speculations about what was observed, and that is understandable weeks or months later.

* Store and retrieve computer information using topical, alphabetical, numerical, and key-word files, and use simple files of the individual's own devising.

* Enter and retrieve information on a computer, using standard software.

* Use appropriate instruments to make direct measurements of length, volume, weight, time interval, and temperature. Besides selecting the right instrument, this skill entails using a precision relevant to the situation.

* Take recordings from standard meter displays, both analog and digital, and make prescribed settings on dials, meters, and switches (pp.137-138).

IMPLICATIONS FOR TEACHING AND RESEARCH

In the view of the AAAS (1989), science teaching consistent with the nature of scientific inquiry will:

* Engage students actively. Students need to have many and varied opportunities for collecting, sorting, and cataloging; observing, note taking, and sketching; interviewing, polling, and surveying; and using hand lenses, microscopes, thermometers, cameras, and other common instruments (p. 147).

* Concentrate on the collection and use of evidence. Students should be given problems--at levels appropriate to their maturity--that require them to decide what evidence is relevant and to offer their own interpretation of what the evidence means. This puts a premium, just as science does, on careful observation and thoughtful analysis. Students need guidance, encouragement, and practice in collecting, sorting and analyzing evidence, and in building arguments based on it. However, if such activities are not to be destructively boring, they must lead to some intellectually satisfying payoff that the students care about" (p. 148).

Typical of resources to assist teachers in these tasks is a handbook (Gabel, 1993) that includes a section on observation as a basic science skill to be taught in elementary school. Another teaching guide (Pauker & Roy, 1991) includes activities that present observing as a science process skill and thinking skill. Similar resources are available in many commercially available instructional materials.

Though curriculum standards and the professional literature of science education promote attention to science process skills, and observation in particular, the research on student conceptions of the role of observation in science seems limited. Reviews of research have shown that when science process skills are emphasized in the classroom, student proficiency on individual skills increases, some transfer of skills to new situations is noted, and skills are retained over time (Padilla, 1990). One study, however, (Haslam & Gunstone, 1996) provides evidence that students tend to view observation as a teacher-directed process rather than a self-directed pursuit of evidence. Student conceptions of evidence-based inferences also seem limited. Surprisingly, many students do not see the process of observation as being particularly relevant to the science learning process (Haslam & Gunstone, 1998). Evaluation studies associated with the current trend toward increased proficiency testing in science will undoubtedly shed more light on student performance in using the tools of observation and the level of skill development in observation techniques. Still there will be open questions regarding the extent to which students can purposefully observe in a self-directed manner to gather evidence in support of their ideas. This is at the heart of doing science, and we have little direct evidence of the extent to which students can couple observations with reasoning to construct models and explanations of natural phenomena.

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