National Science Teaching Association Position Statement

Nature of Science

Introduction

Nature of science (NOS) is a critical component of scientific literacy that enhances students' understandings of science concepts and enables them to make informed decisions about scientifically-based personal and societal issues. NOS is derived not only from the eight science practices delineated in the *Framework for K–12 Science Education* (2012), but also from decades of research supporting the various forms of systematic gathering of information through direct and indirect observations of the natural world and the testing of this information by the various research methods used in science, such as descriptive, correlational, and experimental designs. All science educators and those involved with science teaching and learning should have a shared accurate view of nature of scientific knowledge, and recognize that NOS should be taught explicitly alongside science and engineering practices, disciplinary core ideas, and crosscutting concepts.

It is important to know that this new iteration of NOS improves upon the previous NSTA position statement on this topic (NSTA 2000) that used the label "nature of science," which included a combination of characteristics of scientific knowledge (NOS) and scientific inquiry. It demonstrated the common conflation of how scientific knowledge is developed and its characteristics. Since the recent NSTA position statement on science practices, previously referred to as "inquiry" (NSTA 2018), clearly delineates how knowledge is developed in science, a more appropriate label for the focus of this position statement would be "nature of scientific knowledge" (NOSK). This would clarify the difference between how knowledge is developed from the characteristics of the resulting knowledge. Clearly the two are closely related, but they are different (Lederman & Lederman 2014). However, introducing a new label (i.e., NOSK), given that the *NGSS* refers to the characteristics of scientific knowledge as NOS, would create more confusion. It will be clear that the discussion of NOS here is about the characteristics of scientific knowledge. Additionally, the word "the" is removed preceding NOS to avoid implying that a single set of knowledge characteristics exists.

Why Learn About Nature of Science?

Understanding of NOS is a critical component of scientific literacy. It enhances students' understandings of science concepts and enables them to make informed decisions about scientifically-based personal and societal issues. Although NOS has been viewed as an important educational outcome for science students for more than 100 years, it was Showalter's (1974) work that galvanized NOS as an important construct within the overarching framework of scientific literacy. Admittedly, the phrase *scientific literacy* had been discussed by numerous others before Showalter (e.g., Dewey 1916; Hurd 1958; National Education Association 1918, 1920; National Society for the Study of Education 1960; among others), but it was his work that clearly delineated the dimensions of scientific literacy in a manner that could easily be translated into objectives for science curricula. NOS and science processes (now known as inquiry or practices) were clearly emphasized as equally important as “traditional” science subject matter and should also be taught explicitly, just as is done with other science subject matter (Bybee 2013). The attributes of a scientifically literate individual were later reiterated and elaborated upon by the National Science Teachers Association (NSTA 1982).

Declarations

The National Science Teaching Association endorses the proposition that science, along with its methods, explanations, and generalizations, must be the sole focus of instruction in science classes to the exclusion of all nonscientific or pseudoscientific methods, explanations, generalizations, and products.

NSTA makes the following declarations for science educators to support teaching NOS. The following premises, as well as the terminology (e.g., tentative, subjective, etc.) of nature of science, are critical and developmentally appropriate (for precollege students). They should be understood by all students by the time they graduate high school. The understandings are elaborated slightly beyond the items listed in the *Next Generation Science Standards (NGSS)*.

- Scientific knowledge is simultaneously reliable and subject to change. Having confidence in scientific knowledge is reasonable, while also realizing that such knowledge may be abandoned or modified in light of new evidence or a re-conceptualization of prior evidence and knowledge. The history of science reveals both evolutionary and revolutionary changes. With new evidence and interpretation, old ideas are replaced or supplemented by newer ones. Because scientific knowledge is partly the result of inference, creativity, and subjectivity, it is subject to change (AAAS 1993; Kuhn 1962).
- Although no single universal step-by-step scientific method captures the complexity of doing science, a number of shared values and perspectives characterize a scientific approach to understanding nature. Among these are a demand for naturalistic explanations supported by empirical evidence that are, at least in principle, testable against the natural world. Other shared elements include observations, rational argument, inference, skepticism, peer review, and reproducibility of the work. This characteristic of science is also a component of the idea that “science is a way of knowing” as distinguished from other ways of knowing (Feyerabend 1975; Moore 1993; NGSS Lead States 2013).
- In general, all scientific knowledge is a combination of observations and inferences (Chalmers 1999; Gould 1981). For example, students of all ages pay attention to weather forecasts. Weather forecasters make observations, and their forecasts are inferences. All science textbooks have a picture of the atom, but the picture is really an inference from observable data of how matter behaves.
- Creativity is a vital, yet personal, ingredient in the production of scientific knowledge. It is a component of science as a human endeavor (Bronowski 1956; Hoffman & Torrence 1993; Kuhn 1962).
- Subjectivity is an unavoidable aspect of scientific knowledge. Because “science is a human endeavor,” it is subject to the functions of individual human thinking and perceptions. Although objectivity is always desired in the interpretation of data, some subjectivity is unavoidable and often beneficial (Chalmers 1999; Gould 1981; Laudan 1977).
- Science, by definition, is limited to naturalistic methods and explanations, and as such, is precluded from using supernatural elements in the production of scientific knowledge. This is a component of the recognition that scientific knowledge is empirically based (Hoffman & Torrence 1993).

- A primary goal of science is the formation of theories and laws, which are terms with very specific meanings:
  - Laws are generalizations or universal relationships related to the way that some aspect of the natural world behaves under certain conditions. They describe relationships among what has been observed in the natural world. For example, Boyle's Law describes the relationship between pressure and volume of a gas at a constant temperature (Feynman 1965; Harre 1983; National Academy of Sciences 1998).
  - Theories are inferred explanations of some aspect of the natural world. They provide explanations for what has been stated in scientific laws. Theories do not become laws even with additional evidence; they explain laws. However, not all scientific laws have accompanying explanatory theories (Feynman 1965; Harre 1983; Mayr 1988; National Academy of Sciences 1998; Ruse 1998).
  - Well-established laws and theories must
    - be internally consistent and compatible with the best available evidence;
    - be successfully tested against a wide range of applicable phenomena and evidence; and
    - possess appropriately broad and demonstrable effectiveness in further research (Kuhn 1962; Lakatos 1983; Popper 1968).
- Contributions to science can be made and have been made by people the world over. As a consequence, science does not occur in a vacuum. It affects society and cultures, and it is affected by the society and culture within which it occurs (AAAS 1993; Showalter 1974).
- The scientific questions asked, the observations made, and the conclusions in science are to some extent influenced by the existing state of scientific knowledge, the social and cultural context of the researcher, and the observer's experiences and expectations. Again, scientific knowledge is partially subjective and socially and culturally embedded (Lederman & Lederman 2014; NSTA 2000).

These premises combined provide the foundation for how scientific knowledge is formed and are foundational to nature of science. The NGSS (2013) lists the following eight components of NOS. Given the previous discussion about the differences between how knowledge is developed and what is done with that knowledge as scientific practice, items 1, 5, and 6 are arguably more aligned with science practices (or inquiry) than characteristics of scientific knowledge. Practices and knowledge are obviously entangled in the real world and in classroom instruction, yet it is important for teachers of science to know the difference between science practices and the characteristics of scientific knowledge to best lead students to a comprehensive understanding of nature of science. Items 5 and 7 are a bit vague for concrete use in K–12 classrooms. Consequently, a more concrete discussion of what these items mean was provided in the previous section.

NSTA recommends that by the time they graduate from high school, students should understand the following concepts related to NOS:

- Scientific Investigations Use a Variety of Methods;
- Scientific Knowledge Is Based on Empirical Evidence;
- Scientific Knowledge Is Open to Revision in Light of New Evidence;
- Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena;

- Science Is a Way of Knowing;
- Scientific Knowledge Assumes an Order and Consistency in Natural Systems;
- Science Is a Human Endeavor; and
- Science Addresses Questions About the Natural and Material World.

Concluding Remarks

NOS (i.e., the characteristics of scientific knowledge as derived from how it is produced) has long been recognized as a critical component of scientific literacy. It is necessary knowledge for students to make informed decisions with respect to the ever-increasing scientifically-based personal and societal issues. The research clearly indicates that for students to learn about NOS, it must be planned for and assessed just like any of the instructional goals focusing on science and engineering practices, disciplinary core ideas, and crosscutting concepts (Lederman 2007; Lederman & Lederman 2014). It is not learned by chance, simply by doing science. NOS is best understood by students if it is explicitly addressed within the context of students' learning of science and engineering practices, disciplinary core ideas, and crosscutting concepts. "Explicit" does not mean that the teacher should lecture about NOS. Rather, it refers to reflective discussions among students about the science concepts they are learning (Clough 2011).All aspects of NOS cannot and should not be taught in a single lesson, nor are all aspects developmentally appropriate for all grade levels. For example, understandings of the differences between theories and laws or the cultural embeddedness of science are not developmentally appropriate for K–5 students. Nevertheless, NOS should be included at all grade levels as a unifying theme for the K–12 science curriculum. All too often, NOS is only taught explicitly at the beginning of a science course, independent of any of the science content that will subsequently follow. Instead, NOS should be taught as a unifying theme with the expectation that students' knowledge will progressively become more and more sophisticated as they progress through the K–12 curriculum.

— Adopted by the NSTA Board of Directors, January 2020

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