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Why Teach NOS? Combatting Science Denial and Mistrust

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In today's world of continued science denial and mistrust, where people must make decisions about socioscientific issues such as whether to get a vaccine, wear a mask, or recycle plastic bottles, the importance of understanding the nature of scientific knowledge (NOS) could not be more critical. Science is a way of knowing, yet the public continues to hold misconceptions about what science is. This is evidenced by the presentation of "alternative facts" in the media, political agendas that demonstrate little to no regard for human life, and ignored recommendations for enhancing people's health and the health of our planet. What do science educators need to do to help combat science denial and mistrust?

Trust in science builds from epistemic understanding (Fackler, 2021; Sinatra & Hofer, 2021). Epistemic understanding fosters transparency and critical thinking about scientific claims and recommendations, helping people to manage uncertainties. Understanding that science is inherently dynamic captures the nature of science itself. Scientific knowledge is constructed and represents how we understand the natural world from interpretation of empirical observations and abstractions. The key words here are "empirical" and "interpretation." By promoting understanding of scientific processes and reasoning, as well as uncertainties, qualities, and limitations of scientific knowledge, educators are developing learners' functional scientific literacy necessary to make informed decisions in today's society.

There are suggestions from within the scientific and education communities that teaching NOS may contribute to science denial and mistrust. As Cobern (2020) mentioned, the editors of Nature criticized how NOS is taught in schools (Nature, 2017). They suggest that the way NOS is taught detracts from the durability and trustworthiness of science. Cobern similarly criticized teaching the tentative NOS (2020). If indeed teaching NOS has accidentally contributed to science denial and mistrust, I argue that it isn't because of the construct of NOS. It would be because the construct of NOS is not being taught well, is not being taught comprehensively, and is not being taught in alignment with the construct itself. In other words, poor teaching of NOS, just as in poor teaching of any scientific construct, contributes to misunderstanding and even misuse of information. I contend that the critics and the skeptics of the importance and impact of teaching the tentative NOS are not understanding NOS or employing effective NOS pedagogy.

The implication from these critics is that aspects of NOS are taught as isolated constructs. Thus, according to this position, teaching about the tentative nature of scientific knowledge is to the exclusion of other NOS features that point to *why* scientific knowledge is inherently tentative. Focusing on just one NOS aspect without incorporating connections and reasoning across NOS aspects is simply poor teaching and a poor representation of science epistemology. I can agree that, yes, that type of teaching would likely lead students to misunderstand and mistrust science. Such an approach would be like teaching individual components of an ecosystem without ever showing connections and interdependencies across them.

What is the point? As educators, we need to remember our goal of fostering scientific literacy for informed decision-making. We need to remember that science is more than isolated facts to be recalled on high-stakes assessments. NOS is not a set of declarative statements for students to voice back to us (Lederman, et al., 2002; Schwartz et al., 2013). Therefore, if educators are finding that students, or the general citizenry, are rejecting scientific claims because they mistrust or have adopted an “anything goes” stance about science, then it is time to take a closer look at how NOS is being taught. Again, the implication that teaching NOS contributes to science mistrust because of the tentative NOS indicates an issue with the pedagogical approach, not the construct. Let’s take a closer look.

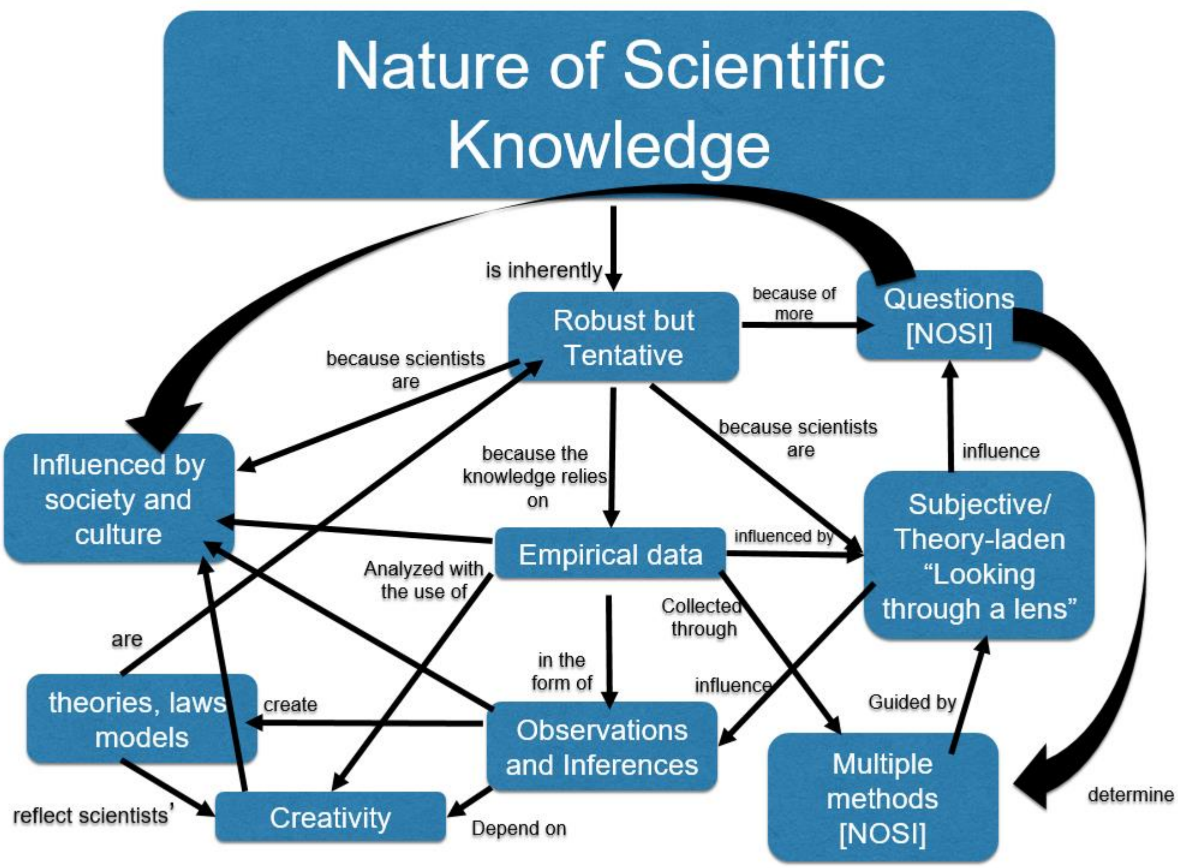
Why is scientific knowledge inherently subject to change? The answer is simple: because science is a human endeavor. The knowledge is developed by humans who function within social and cultural boundaries to gather empirical data in search of understanding the natural world. The knowledge and the inquiries that go into developing that knowledge are creative endeavors, full of observations *and* inferences, and influenced by the theoretical frameworks and individual subjectivities of scientists. Science is progressive, dynamic, and full of questions. As questions are teased out to develop answers, more questions arise. As more information/data are obtained, answers, or our best understanding of phenomena, continue to progress. As Stuart Firestein (2012) recognized, it is what we do not know that is most important because ignorance drives science! Science knowledge is revisionary by the very nature of scientific inquiry because there is no end to the continuous cycles of questions, data, claims, evidence, questions, and on and on… Teaching about NOS knowledge means teaching learners that the claims scientists make are based on empirical evidence developed through analysis of data, inferences, and prior knowledge. Those claims may change due to more evidence and even reevaluation of existing evidence in light of new insights. Indeed, some scientific knowledge has been robustly established and is less likely to change (the law of conservation of energy, for example). While other pursuits of inquiry lead to rapid changes (functionality of SARS-CoV-2, for example). Models of climate change are consistent in predicting disastrous global consequences unless society alters our ways of energy consumption and waste. Nonetheless, these models are not exactly the same. Why are there differences? What should we trust? Without understanding the robust, yet inherently tentative NOS, and that the models are the best understanding of the phenomenon at this time, society has little chance to grasp what is and has been happening in the world of COVID, vaccines, and the global climate crisis.

Tossing scientific claims aside because the news today says something different about COVID than they said yesterday is dangerous and deadly, literally, but we have seen it over and over again. "Confusion about what is scientifically valid has been further blurred by journalistic practices advocating 'balance,' even when such presentations misleadingly distort what scientists know….balance can *become* bias" (Sinatra & Hofer, 2021, p. 162). Sinatra and Hofer go on to say, "Science education can, however, better prepare individuals and citizens by addressing not only content knowledge but also the underlying assumptions of how scientists know what they know….. Fostering a scientific attitude, described as an openness to seek new evidence and a willingness to change one's mind in light of new evidence, is an equally important aspect of science education" (p. 162). In other words, teaching people about the tentative NOS and *why* those claims change helps build trust in science through an understanding that scientific claims are the best we have to date. They are robust because they are evidence-driven.

This may seem simplistic from a philosophical perspective, and it is so intended. We are, after all, teaching children and young adults, not growing a citizenry of philosophers. So let's keep it simple and accessible to the greater population, but keep it meaningful by emphasizing connections across NOS features (Figure 1). In Figure 1, I depict interconnections across NOS and inquiry aspects that are known to be accessible and relevant for learners across grade levels and science disciplines. Clearly, this diagram could show far more connections and features about science and scientific inquiry. This is an example of one way to see integrations. When teaching NOS, explicitly help students see these connections. This integrated approach teaches that our understanding of science can change and still be reliable, useful, and essential for living in today's society. Such knowledge enables critical thinking and evaluation of the validity and utility of claims, recommendations, and their impacts.

Figure 1

Connections across aspects of NOS knowledge



Without a solid understanding of NOS, including and perhaps especially the tentative NOS, how are consumers to sort through the complexities of claims and recommendations they are faced with? NOS helps individuals assess the reliability of scientific information, helps individuals distinguish between valid claims, pseudoscience, and “alternative facts” posed for political agendas. As educators, we have a responsibility to foster epistemic understanding and critical thinking such that society can navigate uncertainties while maintaining trust in science. A foundation of NOS is crucial when engaging with socioscientific issues, where science intersects with societal values, ethics, and diverse perspectives. To suggest that teaching the tentative NOS may lead to mistrust in science is to recognize that teaching isolated NOS aspects is poor teaching.

Where is the danger as relates to NOS and mistrust? The danger lies in *misteaching* NOS just as much as in *not* teaching NOS.

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