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EDITORIAL

Is Nature of Science Going, Going, Going, Gone?

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At the 2012 ASTE International Meeting in Clearwater, Fl, Norman Lederman delivered a plenary address titled, "Nature of Science (NOS) Left Behind." The title was a parody of "No Child Left Behind" and the address bemoaned his concern that the yet to be released *Next Generation Standards* (NGSS Lead States, 2013) would omit or drastically decrease attention to NOS. After all, the construct was given little attention in *Taking Science to School* (NRC, 2007) and the subsequent *A Framework for K-12 Science Education* (NRC, 2012). However, there was still time to revive interest in NOS as the *Next Generation Science Standards* (NGSS) would not be released for another year. What better audience to hear concerns about the disappearance of NOS than the premier organization representing science teacher educators? Was the concern expressed by Lederman just rhetoric before lunch, or was it a foreshadowing of what was to come?

Nature of science (NOS) has been considered an important educational outcome that contributes to scientific literacy for quite some time, and it was strongly emphasized in our last set of standards, the *National Science Education Standards* [NSES] (NRC, 1996). It was considered as subject matter knowledge alongside photosynthesis, Newton's Laws, pH, and plate tectonics. Nevertheless, after the release of the standards until the present, one is hard pressed to see NOS being taught effectively in our science classrooms at any grade level. Nothing was/is really any different today it was since science educators seriously began studying NOS in the late 1950s.

Perhaps a short discussion of the past can help us understand the present and the future. Historically, although NOS has been a perennially prized science education outcome, the construct has had a checkered past, cluttered with issues ranging from construct conceptualization to teaching to assessment. NOS has commonly been conflated with inquiry and this confusion still exists (see Peters-Burton, 2014; Salter

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& Atkins, 2014 for the latest iteration of this confusion). The Peters-Burton editorial also entertains the idea that STEM constitutes a separate discipline and, therefore, has an epistemic nature. But, that will be addressed another day. The Salter and Atkins research (2014) confuses NOS and inquiry, uses a NOS assessment to assess the success of their project and when they find no success they blame the instrument. This is done even though the title of their article focuses on scientific inquiry and NOS is not mentioned. Their problem is that they have misconstrued NOS and conflated it with inquiry. The *Benchmarks for Science Literacy* (AAAS, 1993) placed NOS as an overarching theme that included inquiry. The *National Science Education Standards* (NRC, 1996) situated NOS as separate, but closely related to inquiry. And, now the NGSS (NGSS Lead States, 2013) has situated NOS as primarily a subset of science practices (dare we say the new word for inquiry) and to a lesser degree crosscutting concepts. No wonder NOS continues to be confused with inquiry/practices. Within the literature, inquiry commonly refers to the way scientific knowledge is developed, while NOS commonly refers to the characteristics of the knowledge, as necessarily derived from the manner in which the knowledge is developed.

With respect to pedagogy, debates continue about the most successful approach to teaching NOS even though the empirical research for the past two decades clearly shows that an explicit/reflective approach produces much more learning than an implicit approach. Finally, the assessment of students' understandings of NOS is best accomplished through some combination of "traditional" assessments items and more open-ended probes (most of you know we prefer the open ended probes along with interviews). Still, there is an emerging faction of researchers who think a better approach to assessment is through direct observation of students' behaviors as they navigate science investigations (Sandoval, 2005).

To cloud the waters even further, there is a proliferation of debates asking for a revision to the "definition" of NOS (Allchin, 2011), which essentially just include the addition of aspects of inquiry/practices to the common aspects of NOS. Although critically important for students to understand and be able to do, when conflated with NOS, inquiry/practices typically dominate over NOS. The calls for the re-conceptualization of the NOS construct have now evolved into less than productive concerns about whether what we want students to know should be summarized in a list (Irzik & Nola, 2011). There is really nothing inherently wrong with a list. It is a pedagogical issue. If you just have students memorize and repeat a list, this is a problem. However, if the list is simply used to guide instruction and to help summarize much deeper understandings, lists are quite useful. In the end, isn't the NGSS a list of standards and performance expectations?

With the past and current debates and confusion about NOS, the NGSS (NGSS Lead States, 2013) have chosen to "bury" NOS within the dimensions of science and engineering practices and crosscutting concepts. Perhaps you are thinking that "bury" is a bit too extreme, but given the lack of instructional attention to NOS when the construct was so openly and strongly emphasized in the *National Science Education Standards* (NRC, 1996), "bury" is not an extreme characterization to us. Then again, perhaps statements such as "Indeed, the only consistent characteristic of scientific knowledge across the disciplines is that scientific knowledge itself is

open to revision in light of new evidence" (Appendix H, page 96) should be buried and difficult to find. In the end, NOS is not incorporated into any of the performance expectations. Many of us served on various committees of professional organizations providing feedback to the developers of the NGSS on one or more of their drafts. Lack of attention to NOS was a clearly expressed concern. We served on the NSTA committee that provided Achieve and the NRC with several rounds of feedback. This committee also expressed its concerns about attention to NOS, but we and NSTA ultimately were not satisfied with the final result (NSTA, 2013). To NSTA's credit, they have continued to disseminate publications and provide webinars on how to integrate NOS into the NGSS.

The most significant problem regarding NOS is that the NGSS considers itself to be pedagogically agnostic. That is, in general (to be fair, there are some general comments regarding NOS in Appendix H), no recommendations are provided as to how one would teach the identified outcomes for students, only outcomes are provided. How a teacher gets students to achieve the outcomes is not specified. However, there is a wealth of empirical research, completed over the past two decades, that indicates that NOS is most successfully taught if an explicit/reflective approach is used. Explicit is not synonymous with direct instruction. It simply means that NOS is brought to the forefront at various times during instruction through discussions facilitated by the teacher and reflections among the students. However, the NGSS has not explicitly listed aspects of NOS as stated performance expectations for students. As far as we can tell, the NGSS writers assumed that students will come to understand NOS simply by engaging in science practices and learning about crosscutting concepts. Existing research tells us otherwise.

While growing up in New York during the 1950s and 1960s, Norm was a Yankee fan for part of that time. Their famous play-by-play announcer was Mel Allen. When he was announcing a home run he would say, "that ball is going, going, going, gone." A home run was a good thing if you were a Yankee fan. However, if NOS is going, going, going, gone that would be a BAD thing. The NGSS are the NGSS. It is what it is. Supporters will say that NOS is emphasized in the NGSS. However, as teacher educators we know that the mere inclusion of NOS (and it is difficult to see it) is not enough. We need to provide our pre-service and inservice teachers with guideposts to find NOS and its connections to the explicitly specified dimensions of the NGSS. Then, we need to provide the professional development that will enable teachers to successfully incorporate NOS into their science instruction in an explicit/reflective manner. This is no easy task. This certainly did not happen following the NSES. The task is now more difficult than before because of how NOS is embedded in the NGSS. BUT, we do have a second chance. We need to make the best of it before NOS is truly gone.

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