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Evidence and rationale for expanding The Views of Nature of Science Questionnaire

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Abstract

In an attempt to understand nature of science (NOS) conceptions held by learners in greater detail, researchers have steadily become more reliant on open-ended measures. The Views of Science Questionnaire (VNOS) is the most frequently used open-ended instrument. Conceptually grounded in many of the same aspects emphasized in the *Next Generation Science Standards*, the VNOS-C is appropriate for capturing the views of secondary school students and adults along 10 dimensions related to NOS. However, it has been observed that the 10-item VNOS-C seems to have difficulty uncovering some particular NOS aspects, or rather respondents may need additional prompting. Two new items have been developed and administered to expand the VNOS instrument (VNOS-CE). The present study focuses on evaluating whether these items function as intended, soliciting responses for the target NOS aspects, and whether these contributions add value to the instrument as a whole. Data comes from 37 pre- and in-service elementary, middle and secondary teachers. Results suggest one of the items adds considerable breadth, eliciting responses from multiple NOS aspects, while the other adds much needed depth related to one aspect, social NOS. Implications for the field and assessment of NOS are discussed.

Evidence and rationale for expanding The Views of Nature of Science Questionnaire

Background

Developing informed views of nature of science (NOS) has been a focus of past reform documents and continues to be a focus of current reform efforts, such as the *Next Generation Science Standards (NGSS)*. In line with this continued interest in understanding students' views of NOS, methods of assessing these views have evolved over the decades to reflect the needs of researchers and best practices in capturing participants' views of NOS. Leading to the present, a shift has been made from theoretically- and empirically-driven forced-choice instruments to open-ended instruments. The Views of Nature of Science Questionnaire (VNOS) is the most commonly used open-ended instrument for assessing views of NOS considered appropriate for K-12 science instruction (Kampourakis 2016; Smith, Lederman, Bell, McComas, & Clough 1997). Form C is the most widely used to date. (VNOS-C; Abd-El-Khalick & Lederman, 2000).

The VNOS-C utilizes 10 open-ended questions to capture respondents' views of NOS. Researchers assign qualitative codes to these often lengthy responses (i.e., informed, partially informed, naïve, or silent) for each aspect of NOS that the instrument measures. Drawing from the consensus perspective, 10 target NOS aspects are emphasized: the empirical, tentative, inferential, creative, theory-driven, and social NOS, in addition to the myth of "The Scientific Method," the nature of scientific theories and laws, and the social and cultural embeddedness of science. It is important to note that evidence of participants' views of a single aspect of NOS may be found in responses to several questions. To illustrate, Items 6 and 7 on the VNOS-C were designed to probe on respondents' views of the same NOS aspects (Lederman et al., 2002, p. 509), namely, the inferential, creative, and tentative NOS. These items differ in context, Item 6 connects to the physical sciences and atomic theory whereas Item 7 uses the construct of species from the biological sciences to ask a similar question. Looking at responses to the entire questionnaire, holistically, provides researchers with a wealth of information.

The administration procedures for the VNOS encourage the use of follow-up interviews. In addition to helping to clarify participants' responses to the VNOS, the authors explain that follow-up interviews reduce ambiguities and ensure a high degree of congruence between researchers' interpretation and respondents' intended meaning in relation to their understandings of NOS (Abd-El-Khalick, 2014). The recommended interview questions focus on written responses (e.g., could you read your response to question...) by prompting clarification (e.g., could you give an example of what you meant by...) and encouraging consistency (e.g., how does your response on #X relate to your response on #Y?). Due to this structure, however, these questions may not be able to draw out silent or underdeveloped ideas effectively.

It is important to reiterate the number of questions on the VNOS and the number of target NOS aspects emphasized were not designed to correspond one-to-one. A recent study examined responses to the VNOS-C questionnaire (n=36), revealing that respondents made connections to between 3 and 8 aspects on any given question (Brunner, Summers, Myers, & Abd-El-Khalick, 2016). Some questions seemed to elicit connections to fewer NOS aspects, but, at times, in a more consistent manner. For example, nearly all of the questionnaires analyzed, 34 of 36, made some connection to the social and cultural embeddedness of science in response to Item 10.

Another finding from this study was that the social nature of science was only addressed in one item, Item 7, across the analyzed questionnaires. Moreover, social NOS was judged to be silent with insufficient information elicited to evaluate respondents' views in the majority of responses. This particular study illustrates that a greater number of opportunities to tap into these two specific NOS aspects may be needed.

The purpose of this study is to thoughtfully consider the addition of two items to the well-established VNOS-C. From our perspective these additional prompts would provide a systematic way of increasing the number of opportunities respondents would be likely to connect, and encourage meaningful detail, related to particular NOS aspects. In relation to this overarching goal, we investigated two research questions pertaining to the performance of these proposed additions:

1. To what extent do the new questions garner responses to the intended NOS aspects?
2. To what extent do the two additional questions encourage responses beyond the standard 10 questions of the VNOS-C?

By addressing these questions, we illuminate patterns of responses for the 10 NOS aspects by tabulating occurrences across the 12 items of the VNOS-C as expanded (VNOS-CE). We assess the impact of the new items by considering the evidence generated by each question for particular NOS aspects, comparing the overall codes for the VNOS-C and expanded questions.

Method

Instrumentation. Given the VNOS-CE is an expanded version of the VNOS-C it draws heavily from the established content validity. Sireci (1998) articulated four elements needed to support content validity, domain definition, domain representation, domain relevance, and appropriateness of test construction procedures. In summary, these elements span the theoretical to the operational way the intended outcomes are assessed, adhering to the appropriateness of the item format and in consideration of the intended audience (Sireci & Faulkner-Bond, 2014). Content validity and reliability of the VNOS have been demonstrated in multiple instances, and Bell and Lederman (2003) established the construct validity of the instrument. To be clear, no additional NOS constructs are proposed as a part of the study. The two items simply provide additional opportunities for respondents to address these constructs, or portions thereof. Likewise, the response formats of the newly added items mirror extant item structures, described below. Ensuring the context of assessment the referent is familiar, accessible, or understandable to the respondent is essential. In this case of NOS this might include a specific scientific theory or controversy, a socioscientific issue, or a context common to school science (Abd-El-Khalick, 2014). The new open-ended items discussed in this study were initially developed by one of the VNOS authors with collaboration and input from science teachers.

The first new item, denoted Item 11, appeared as a simple question on the VNOS-CE similar in structure to Item 3. Item 11 was designed to help garner views about the generation of scientific knowledge, including connections to the social NOS as well as the importance of creativity and imagination in this process. The latter dimension can be described as follows:

Generating scientific knowledge also involves human imagination and creativity. Science ... is not a lifeless, entirely rational and orderly activity.... scientific entities, such as

atoms and species are functional theoretical models rather than copies of reality.
(Lederman et al., 2002, p. 500)

The second new item, Item 12, was structured with a more detailed referent similar to Item 10. It is worth highlighting this structure because some critics have urged more contextualized questions are needed to evaluate NOS views (e.g., Allchin, 2010). Item 12 was designed to draw out understandings about how science is embedded in, affects, and is affected by the larger social and cultural milieu in which it is practiced. Recently other scholars have called for more attention to these issues, particularly the relationship between funding and work in science (e.g., Erduran & Dagher, 2014). The addition is meant to shed light on the dimension as described:

The social and cultural embeddedness of scientific knowledge, where it is held that Science as a human enterprise is practiced in the context of a larger culture and its practitioners are the product of that culture. Science, it follows, affects and is affected by the various elements and intellectual spheres of the culture in which it is embedded. (p. 501)

Data sources. Thirty-seven completed VNOS-CE questionnaires were selected for this study. Responses were collected from 28 pre-service science teachers, 6 from the elementary level and 22 from the middle and secondary levels. The remaining 9 questionnaires were completed by in-service teachers. All questionnaires selected for the study were collected before any formal NOS-related instruction and/or intervention.

Coding. Coding occurred in two phases. In the first phase, the VNOS-CE questionnaires were read through and assigned qualitative codes according to the procedure set out by Lederman and colleagues (2002). This coding was holistic in nature, as the questionnaires were read through in their entirety with specific references to aspects of NOS being identified in each question. The researchers then read through the references for each aspect and assigned a qualitative code. Responses that were in line with, and fully addressed, the NOS aspects were assigned a code of *informed*. Responses that either produced mixed messages (e.g., a response states in one question that science changes as scientists gather more information but in another that scientific laws are absolute and do not change) or did not fully address the NOS aspects were assigned a code of *partially informed*. Responses that were not in line with the NOS aspects were assigned codes of *naïve*. If a participant did not address a NOS aspect at any point in the questionnaire, a code of *silent* was assigned. Each aspect was given a code, resulting in 10 codes per participant. In the second phase, the researchers searched for each time a respondent addressed a certain aspect in their response. Specific quotes from the questionnaires were identified and categorized by the question in which they appeared. This allowed for the researchers to identify the aspects respondents addressed in each question and the frequency with which participants responded to each aspect in their questionnaires. This coding scheme allowed for comparisons to focus on the contributions of the new items, judging both the aspects elicited and the quality of those contributions.

Select Findings

On average, Item 11 elicited connections to 2.3 NOS aspects per response (ranging 1-3), whereas responses to Item 12 connected to about 1 aspect for nearly all participants in the sample (ranging 1-2). Note that both questions were successful in garnering NOS views, to some extent,

for all participants. This is not an indication of *quality*, or the adequacy of the views captured, but it does suggest the questions add to the evidence in a somewhat consistent way.

Item 11 was intended to stimulate responses related to the production of scientific knowledge including the role of creativity in the process. Analysis focused solely on the connections to NOS aspects generated in response to this question, without gauging the extent to which individual instances were naïve- or informed-leaning. Figure 1 showcases the distribution of connections, reported as a percentage, across 8 NOS aspects with the highest proportion of these instances relating to the Myth of “The Scientific Method (26.3%), tentative and empirical NOS (both 18.4%). Few instances (2.6%) related to creative NOS in this sample, but bear in mind an extant item (Item 8) directly asks respondents about this aspect (“Do scientists use their creativity and imagination during their investigations?”).

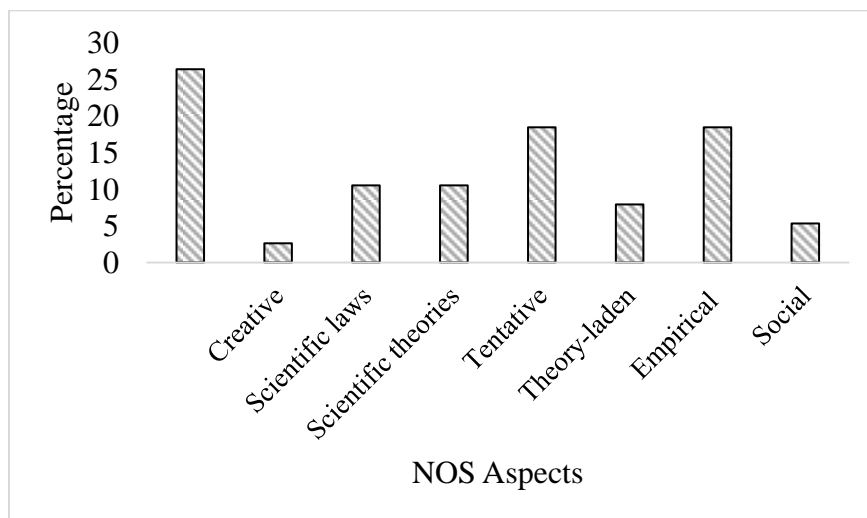


Figure 1. Connections to NOS Aspects on Expanded Question 11 Reported as a Percentage.

A high proportion of NOS instances identified in response to Item 12 pertained to social NOS (81.3%) with some instances of the tentative (6.5%) and social and cultural embeddedness (12.5%). This finding is not surprising given the structure of the item, but it is important to ascertain its performance as intended. One particular respondent, for example, addressed the social NOS in both Items 11 and 12, stating, “The conclusions drawn then are re-examined by other scientists...” and “Scientists’ research is often peer-reviewed extensively before being presented or published.” The same respondent also spoke to the Myth of “The Scientific Method” in response to Item 11. The aforementioned aspects were only elicited, in this case, on Items 11 and 12. Prior investigation of the distribution of VNOS responses on the VNOS-C indicated that, as written, the instrument may not provide sufficient opportunity for participants’ to address the social nature of science (Brunner, Summers, Myers, & Abd-El-Khalick, 2016). Considering the contributions of the added items, we noted multiple instances where the responses generated either informed the overall codes or supplied the entirety of the evidence in the present study.

Contributions to the Field

Reform efforts (e.g., Achieve, 2012) continue to stress the need for learners to develop robust understandings about the nature of the scientific enterprise. As such, research questions about the specific ways in which NOS understandings are learned, elicited, and assessed remain critical to the field. The present study reports on efforts to improve assessment practices in the field by adding two items to the VNOS instrument. Further these items have been successful in tapping into constructs, such as social NOS, which have been difficult to uncover with the VNOS-C. Discussions about any addition to an established instrument warrants thorough consideration. Given the widespread use of the VNOS, constituting 57% of instrument use between 2000 and 2012 (Abd-El-Khalick, 2014), many researchers are likely to be interested in this conversation. We argue the items presented in the expanded version (VNOS-CE) add to the instrument as a whole by creating valuable opportunities for participants to articulate their views. As always, it is the *quality* of responses that should be used to determine the sophistication of respondents views regarding NOS, not the *quantity*, but these added questions may help to detect nuance and provide evidence for ongoing investigation.

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