Spectra Undergraduate Research Journal
Volume 2, Issue 2
Office of Undergraduate Research
University of Nevada, Las Vegas
digitalscholarship.unlv.edu/spectra/

OPEN ACCESS

Category
Arts, Humanities, and Social Sciences > Education > Science Education
Received
June 14, 2022
Accepted
August 19, 2022
Published
August 31, 2022
Article Title
Understanding Inservice Middle School Teachers' Views of Nature of Science (VNOS)
Authors
Merika Charupoom (MC)[1*], Yasmeen Hernandez (YH)[2*], Emily Carter (EC)[2], Nicole Juliana Thomas, M.S. (NJT)[3], and Tina Vo, Ph.D. (TV)[3]
Author Affiliations
[1]Department of Environmental and Occupational Health, University of Nevada, Las Vegas, Las Vegas, NV, USA. [2]School of Life Sciences, University of Nevada, Las Vegas, Las Vegas, NV, USA. [3]Department of Teaching and Learning, University of Nevada, Las Vegas, Las Vegas, NV, USA.
Corresponding Author
*Merika Charupoom, charum1@unlv.nevada.edu https://orcid.org/0000-0002-1118-2968 *Yasmeen Hernandez, hernay2@unlv.nevada.edu https://orcid.org/0000-0003-3418-9182
Author Contributions
*Charupoom & Hernandez share first author responsibility for this paper, and the work is reflective of equal effort on both of their parts. MC: Substantially contributed source curation, literature review, drafting of paper, formal analysis, writing of the original draft, and reviewing and editing of the manuscript. YH: Substantially contributed source curation, literature review, drafting of paper, formal analysis, writing of the original draft, and reviewing and editing of the manuscript. EC: Supported research through literature review. NJT: Assisted in data analysis and manuscript editing. TV: Supervised the project, research and the writing.
Copyright
Articles in Spectra are freely available under a Creative Commons Attribution License (CC BY 4.0) which allows others to re-use the work without permission as long as the work is properly cited.
ISSN
2766-7227
Data Availability Statement
The data for this project is available upon request to the PI of this project Tina Vo (tina.vo@unlv.edu).
Conflicts of Interest
The author declares that they have no competing interests.
Ethical Considerations
This research is covered by a Category 1 exempt IRB [UNLV-2021-247 Investigating the impact of OpenSciEd], held by Dr. Tina Vo. All authors are CITI certified and were the only researchers to work with anonymized data.
Funding
This research was made possible by the UNLV Office of Undergraduate Research's (OUR) 2021 Undergraduate Research Stimulus Program (URSP) Track 1: Undergraduate Research Mentor-Mentee Program.
Recommended Citation
Charupoom, M., Hernandez, Y., Carter, E., Thomas, N. J., & Vo, T. (2022). Understanding inservice middle school teachers' Views of Nature of Science (VNOS). *Spectra Undergraduate Research Journal, 2*(2), 89-101. https://doi.org/10.9741/2766-7227.1022

Spectra Undergraduate Research Journal
Volume 2, Issue 2
Office of Undergraduate Research
University of Nevada, Las Vegas
digitalscholarship.unlv.edu/spectra/

Understanding Inservice Middle School Teachers' Views of Nature of Science (VNOS)

Merika Charupoom[1], Yasmeen Hernandez[2], Emily Carter[2], Nicole Juliana Thomas, M.S.[3], and Tina Vo, Ph.D.[3]

Author Affiliations:
[1]Department of Environmental and Occupational Health, University of Nevada, Las Vegas, Las Vegas, NV, USA.
[2]School of Life Sciences, University of Nevada, Las Vegas, Las Vegas, NV, USA.
[3]Department of Teaching and Learning, University of Nevada, Las Vegas, Las Vegas, NV, USA.

Abstract

The Nature of Science (NOS) is a component of science literacy that supports critical thinking around science concepts, speaking to how and why science is conducted and connected to creating data and evidence. NOS is designed to be more than the standardized lessons of science; it helps children critically analyze and solve real-world and societal issues using scientific knowledge. The interpretation of science varies between the ideology and beliefs of each individual. Given the importance of this idea, it is necessary that teachers be able to provide NOS opportunities to students; however, first, they must have a firm grasp of the concept. To that end, we have created a qualitative study using the Views of Nature of Science (VNOS-D+) questionnaire to understand how a group of middle school science teachers conceptualize the NOS. The VNOS-D+ was administered to a cohort of teachers and administrators (n=23) within a Large Urban School District. The data was analyzed using the VNOS key and then open-coded by three reviewers. The results found that participants had an emergent and developing understanding of the NOS and should be supported to develop a robust NOS perspective. Given this finding, future research, professional development, and educational curriculums should support teachers to continually engage with NOS explicitly and implicitly to grow their understanding of the topic.

Keywords: Nature of Science (NOS), VNOS, middle school teachers, science education

Democritus, born around 460 BC, was a known natural philosopher who posited ideas about atomic theory (Berryman, 2016). He, like many other natural philosophers (e.g., Plato, Hypatia, Galileo), were fascinated with how and why the world functioned, attempting to posit questions about the NOS long before the idea of scientists existed. The Nature of Science (NOS) is a component of contemporary science literacy that supports critical thinking around science concepts, speaking to how and why science is conducted and connected to the creation of data and evidence (Lederman et al., 2013). The NOS highlights that science shaped the world we live in through sociology, exploration, and explanation. Currently, within contemporary Western schooling (i.e., K-16), the idea of "science" is taught as a set of rigid and unchangeable concepts; however, it is more akin to an abstract, flexible, and constantly changing body of knowledge. Many science experiences tend to revolve around memorization, generalization, and recitation of scientific facts and theories. Science goes beyond empirical evidence and hypotheses, and it can be applied fundamentally in real-world situations (O'Neill, 2011). When students have a strong

https://doi.org/10.9741/2766-7227.1022

background understanding of the scope of science, it further enhances their abilities as scientists in the future. Being able to understand scientific literacy would allow students to be informed citizens who make informed decisions.

NOS is designed to be more than the standardized lessons of science - it helps children critically analyze and solve real-world and societal issues using scientific knowledge. Science education relies on hard facts and textbook ideas that students may struggle to retain and store the information long-term without developing their science literacy and how they can apply to real-world situations (Lederman et al., 2002). It has become increasingly important to study the ways in which both students and teachers comprehend the NOS. The understanding of scientific knowledge and how to obtain that knowledge is an important component of science literacy. In a science classroom, the role of the instructor or educator is principal in conveying the knowledge to the ones being educated. NOS, as a construct, often speaks to the characteristics, values, and fundamentals that comprise science. It is important that students at all grade levels can access the proper foundational understanding of these fundamental concepts to have the option of pursuing a science career or even engaging in the world as a scientifically literate citizen. The interpretation of science varies between the ideology and beliefs of each individual. To further understand how teachers provide this opportunity to students, it is important to understand the knowledge of the educator.

Teachers are responsible for explicit instruction that helps students develop a deeper understanding of science and their application of that knowledge in society. They also play an essential role in the development of students' ideas and the improvement of student learning. They often provide the most tangible science opportunities for students, and it is important that these opportunities be as authentic and reflective of actual science as possible. A person must have an adequate understanding of a concept in order to communicate that knowledge effectively for the "knowledge train" to continue from person to person; thus in order to teach about the NOS, a teacher must have a strong grasp of the concept. As middle school is one of the first opportunities students have to engage with science-specific courses, we hope to support additional endeavors in science literacy through working with middle school teachers.

The purpose of this study is to analyze the perspective of science educators and their knowledge of the NOS construct to see how they perceive the connection to common misconceptions in science. Focusing on the teachers' understanding of science can help us better understand how well this knowledge will translate to the students. This research is structured around the following research question: How well do middle school teachers understand the foundations of the nature of science?

Background & Literature Review

Current State of Students in STEM/ Science: There has been a significant increase in Science & Engineering degrees conferred within the United States for a few decades, showing a rising interest and need for science literacy within the workforce; however, these numbers are often skewed towards white men representing the majority of this growth (National Science Board, 2022). Research has indicated that increased understanding of the NOS can help ameliorate the differentiated opportunities provided to women and minoritized populations (Biachini & Solomon, 2003; Walls et al., 2013). Given this opportunity, it is important to understand some of the literature aligned with this research.

Nature of Science: NOS is usually referred to as a way of understanding or knowing the values and beliefs that is the fundament of scientific knowledge and its development (Lederman et al., 2013; Lederman, 2007). There are certain procedures and protocols that need to be followed. NOS is the ability to understand and explain science and its' different aspects -- it is the ability to challenge theories and create new experiments. The concepts of NOS have the ability to change over time and are known to have changed over time (Lederman et al., 2013). Therefore, it proposes the idea that science has areas yet to be discovered.

The NOS may be easy for a scientist to explain, but when teachers have undergone studies, the findings were "inconsistent" (Sarkar & Gomes, 2010). Educators are expected to teach certain aspects of the NOS, such as "what is a theory" and "what is a law in science" and how they differ. NOS is often expected to be taught in the classroom, but some educators do not have the training on how to teach the NOS (Leden et al., 2015). NOS is a critical component to understand because science is often taught to be rigid, which can constrain students' ability to further question and bring up challenges of a scientific concept that may lead to the ability to conduct an experiment. Science in school is often taught to be an algorithm; there is no explanation of experiments that are meant to be failed, revised, and repeated. Researchers do not just conduct one experiment and call it a day. Conducting a single experience without replication can often lead to poor data and misconceptions; however, this is often the approach in K-16 science.

Misconceptions of Science: Misconceptions in science literacy and knowledge appear in all areas of science and age groups. Misconceptions, in this study, are defined as the inaccurate understanding of scientific information that students develop from reliable sources like parents and teachers (Fuchs et al., 2021). It can occur because of the inconsistency in science curriculums among institutions and education systems (Gomez-Zwiep, 2008). Misconceptions can be passed down and become misconstrued as it essentially creates a gap between knowledge through socio-constructs and knowledge through fundamental classroom instruction, thus affecting our education system and in turn decreasing the academic success of students. Without a strong understanding of the NOS, some of these misconceptions may never be corrected. For example, many people remember learning about Mendelian genetic traits and Punnett squares in introductory biology. However, there now exists a misconception that this is the only way that inheritance functions. In fact, there is a large group of non-Mendelian traits that do not adhere to Punnett squares. Individuals with an understanding of the NOS are able to realize their misconceptions and accept the new information, while others who feel like science is a concrete grouping of facts may reject this idea.

It has been observed that the way a student navigates through their social learning environment and fundamental classroom development parallels their teachers' way of navigation; whether through creating claims of knowledge, engaging in argumentation, or solving problems (Okur & Gungor Seyhan, 2021). Teachers should be made aware of these challenges in problem-solving and reasoning to support students' understanding that science literacy goes beyond basic scientific principles, but the application of science itself can be applied in recognizing a problem and creating a solution. One way to help us understand whether science educators have a strong foundational understanding of science and its NOS construct is to use an open-ended questionnaire that is developed to measure teachers' perception of science: Views of Nature of Science (VNOS-D+). Studies have shown that many teachers implement NOS and other components such as "Driving Board Questions" and "Project-Based Learning" concepts into their curriculum to enhance connectedness to lesson activities and to develop the extent of student-centeredness (Maeng et al., 2018).

The NOS refers to the justification of "how" and "why"; this concept has risen from different values and beliefs of science making the NOS a complex concept. The goal of this concept is to be able to make informed decisions based on scientific literacy. Due to the complexity of what the NOS is, there are always challenges to how such aspects are learned and how they can be taught in an effective way. According to Lederman (2013), using a methods course specifically oriented towards NOS could significantly improve science literacy. Science is fluid and has the ability to change through new discoveries and experiments; this leads to the discussion of what aspects should define the NOS. This challenge brings up the concept of what should be expected from a teacher and if training should be provided. There are cases where teachers are expected to teach about the NOS, but training on how to teach NOS is unavailable, leading to inconsistent NOS answers in the studies (Leden et al., 2015). Proper training to help teachers implement the NOS in their classrooms can benefit teachers and students in the long run. Through lessons and interventions, studies have shown improvement in NOS understanding (Metin Peten, 2021). This increased knowledge can impact teachers' ability to provide more authentic science experiences to students (Schwartz et al., 2004).

The main goal of teacher interventions is to provide professional growth for teachers, which they can apply to their students. Teacher interventions, when regarding the NOS have been effective; they provide teachers with the skills to reinforce their NOS aspects and apply these skills in their classroom. (Adibelli-Sahin & Deniz, 2017) The ability to change a person's perspective on NOS concepts can be done so through a variety of materials, such as "classroom experiences, discussions, readings, and activities that exemplify NOS aspects and connections across aspects" (Mesci & Schwartz, 2016). These interventions, such as graduate courses, are designed to reinforce NOS concepts and have a pre and post-assessment that allows the teacher and researchers an opportunity to understand which NOS aspects the teachers are informed about and which NOS aspects are at the developing stage (Deniz & Adibelli, 2015). Allowing teachers to be informed on the misconceptions they might have had concerning a NOS concept and how to strengthen and reinforce such NOS concept. There are certain factors when teaching NOS aspects in a classroom that teachers account for when teaching; certain NOS aspects taught to students should be appropriate for their grade level and which NOS aspects seem suitable and or valuable for the lesson (Deniz & Adibelli, 2015).

The explicit effective approach during interventions was a fundamental approach for teachers to improve their understanding of NOS aspects. This approach focused on the skills of asking questions and allowing room for discussion regarding NOS aspects. (Mesci & Schwartz, 2016). In two separate studies, this approach used different teacher intervention lengths: a five-day intervention and a year-long intervention; both of these studies showed improvement in the NOS aspect understanding of the participants (Deniz & Akerson, 2013; Adibelli-Sahin & Deniz, 2017).

Our understanding of NOS aspects is susceptible to change. Participants' willingness and motivation to learn about the areas in which they can improve was a factor seen in researchers who showed no improvement in their understanding of NOS aspects (Schwartz et al., 2004) at the end of teacher interventions.

Methods

This research seeks to investigate science teachers' foundational understanding, views, and interpretation of science based on a science literacy framework and the NOS. A qualitative study using descriptive statistics was used in this research. Descriptive statistics can act as simple way of summarizing and organizing data to describe the relationship between variables (Kaur et al., 2018).

Context & Participants: Participants in this study (n=23) were middle school science teachers within a Large Urban School District. All participants were science educators with at least three years of teaching experience, with four teachers having more than ten years of science teaching. This research was conducted over the course of a week-long professional learning (PL) opportunity for teachers who were interested in investigating the implementation of an open-source science curriculum. Teachers in this PL self-selected into the summer program and were also committed to continuing engagement through the school year.

Instrument and Data: The Views of Nature of Science Form D+ (VNOS-D+) questionnaire was administered to participants at the beginning of the PL. This instrument is a variation of the original VNOS (Lederman et al., 2002) revalidated to be a short answer questionnaire (Lederman & Khisfe, 2002) specifically for teachers. This 14-item open-ended VNOS-D+ questionnaire gathers teachers' ideas and opinions about the NOS towards situating their ideas of NOS onto a spectrum. VNOS-D+ was designed to understand the level of understanding and conceptualization of different aspects of science; a sample of the VNOS-D+ is presented in Appendix A. The first two items are about the basic understandings of science and empirical knowledge. Seven items focus on the tentativeness, observation, and inference aspects of science and the remaining five are on creativity, social, and cultural embeddedness. The questions were free responses that enabled the participants to write as much or as little as they needed to answer every part of the question to the best of their ability.

Once participants completed all the short responses via Qualtrics, the data was collected and the PI anonymized and cleaned the data into a clean data set. The clean data set was provided to the first, second, and third authors to analyze.

Data Analyses

In order to engage with data analysis, the first three authors had to become familiarized with the coding objectives of the VNOS-D+ in which the instrument creators operationalized seven aspects of NOS: Distinction between observations and inferences, Empirical, Creative and imaginative, Subjective Scientific knowledge, Social and culture embeddedness, Tentative, Distinction between scientific laws and theories (Appendix B). Different facets were captured in each of the VNOS-D+

questions (see Lederman et al., 2002), which coders used to score each question response. When coding, a numerical score was assigned to the participants' responses when compared to the standardized Answer Key ranging from a score of 0 to 3 (0= Inadequate information to determine; 1= Naive responses are not consistent with any part of NOS aspect; 2= Transitionals responses are consistent with some, but not all, parts of NOS aspect; 3 = Informed responses are consistent and addresses ALL parts of NOS aspect).

Once coders were familiar with the assessment, they engaged with multiple rounds of coding using the VNOS-D+ Answer Key (sample provided in Appendix B). First, a subset of 5 of the 23 teachers' data was chosen to code as a group to obtain interrater agreement. Each question had a set of five responses for each of the researchers to analyze. Coders looked at the first question, rated each set of the answers individually, and discussed their ratings until 100% agreement was researched. Then coder moved to the second question, rated each response individually, and then shared their ratings until a 100% agreement was reached. This continued until all the questions had ratings. Upon completion, each coder rated the remaining responses across all questions individually, sharing their results. Appendix C provides an example of how different responses were coded. 0= Inadequate information to determine; 1= Naive responses are not consistent with any part of the NOS aspect; 2= Transitionals responses are consistent with some, but not all, parts of NOS aspect; 3 = Informed responses are consistent and address ALL parts of NOS aspect. This paper reports on the first step in a multi-stage study were researchers highlight teachers' engagement with VNOS-D+ questions. Future, analysis will work towards connecting teachers' scores with the operationalized aspects of the VNOS-D+ (e.g., Distinction between observations and inferences, Empirical, Creative and imaginative).

Results and Key Findings

Using the VNOS-D+ survey and scoring rubric, we were able to answer our research question: How well do middle school teachers understand the foundations of the nature of science (NOS)? We found that the majority of responses were scored as a score of 1 (naive), with a total of 191 incidences. The score of 0 (inadequate) had 69 incidences, the score of 2 (transitional) had 39 incidences, and the score of 3 (informed) had a total of 0 incidences (Appendix D). All scores discussed are respectively in Figure 4. Interestingly, while most responses were scored as 1, we observed that no response received a score of 3 (informed) in any of the questions. We believe that this indicates that most middle school sciences teachers had some understanding of the NOS, but there was still room for growth.

Additionally, the data indicated that while some teachers did have higher cumulative scores, a majority of the participants >60% had at least one transitional score of 2; however, this was not consistent across any one question. Also, given the unpredictability where individual teachers had transitional knowledge, we hypothesize teachers may have developed their knowledge on their own rather than through specific professional development. This highlights the resilience of teachers and represents a high level of self-motivation toward learning.

Implications & Limitations

This VNOS-D+ questionnaire was not just designed to test science concepts, but instead to demonstrate the practicality in which students can use their knowledge, values, and beliefs in science to the solve-real world and societal issues. The VNOS-D+ help researchers further assess the level of understanding teachers have of NOS to share this information with educators and others in the education field. A limitation of this work exists in how the data were analyzed. The analysis of this research focused on to understanding how well teachers were able to engage with individual questions of the VNOS-D+. Looking forward the next step for this research is to continue pushing this analysis forward towards understanding teachers' aggregate scores, and how those scores reflect on teachers' understanding of NOS as a whole. While teachers play an important role in molding and nurturing students' knowledge through education, information is always advancing and changing. It is important for teachers to acknowledge that misconceptions in science are common and continue to be resilient, educating themselves to effectively translate that information to students. The findings from this research study indicate that teachers might need foundational support around understanding science. This lack of support and resources for teachers may cause misconceptions for their students in the classroom. The goal of this research is to understand the areas of the NOS understanding in teachers and how they may be strengthened through resources, such as workshops and academic development that can benefit both teachers and students.

This preceding knowledge of the understanding of a population of in-service teachers in a Large Urban School District can serve as a preliminary understanding for more in-depth research with a larger cohort that can better represent the middle school in-service teachers in the District. Expanding the cohort will enable us to get a robust understanding of the science curriculum; researchers may also want to administer the VNOS-D+ questionnaire to teachers from K-12 instead of focusing on just in-service middle school science teachers.

Conclusions and Future Directions

By having a general view of what teachers' thoughts are on the Nature of Science, there are options for future interventions if needed. Future interventions can include professional development workshops for teachers and/or student interventions. With research and further studies, there is the possibility of enhancing students' learning during different grade levels. This would also allow students to strengthen and discover various STEM fields through these lessons and interventions.

For more in-depth research, determining how well the teachers are able to learn about the NOS and translate that knowledge into their teachings would further help researchers reduce the knowledge gap in students. In a future study, there could be an administration of a pre and post- VNOS-D+ questionnaire with the addition of training and teacher development workshops. This would give the opportunity for teachers to examine areas where they can improve and strengthen their NOS understanding while obtaining training on how to teach the NOS.

We would also like to explore the teacher-student relationship and determine how influential a teacher is in understanding their students' NOS knowledge by assessing the students about the NOS. With this, we can compare the responses of teachers and students to see any parallels in knowledge to see how teachers' praxis is connected to students' learning. The understanding of instructors is connected to students' overall engagement with the NOS. Because of this, the work of teachers' self-motivated NOS growth is a fascinating finding in this research. By supporting NOS growth, teachers support students' ability to apply scientific knowledge to real life, fundamentally and philosophically, helping them become more science literate.

Acknowledgements

This project would like to acknowledge the dedicated teachers who participated in this project.

References

Adibelli-Sahin, E., & Deniz, H. (2017). Elementary teachers' perceptions about the effective features of explicit-reflective nature of science instruction. *International Journal of Science Education, 39*(6), 761–790. https://doi.org/10.1080/09500693.2017.1308035

Akerson, V., & Deniz, H. (2013). Examining the impact of a professional development program on elementary teachers' views of nature of science and nature of scientific inquiry, and science teaching efficacy beliefs. *Electronic Journal for Research in Science & Mathematics Education, 17*(3), 1-19 https://ejrsme.icrsme.com/article/view/9641

Berryman, S. (2016). "Democritus." *The Stanford Encyclopedia of Philosophy*, Edward N. Zalta (ed.). https://plato.stanford.edu/archives/win2016/entries/democritus

Bianchini, J. A., & Solomon, E. M. (2003). Constructing views of science tied to issues of equity and diversity: A study of beginning science teachers. *Journal of Research in Science Teaching, 40*(1), 53-76. https://doi.org/10.1002/tea.10060

Deniz, H., & Akerson, V. (2013). Examining the impact of a professional development program on Elementary teachers' views of Nature of Science and Nature of Scientific inquiry, and Science teaching efficacy beliefs. *Electronic Journal of Science Education, 17(3)*, 1-19. Retrieved from https://files.eric.ed.gov/fulltext/EJ867290.pdf

Deniz, H., & Adibelli, E. (2015). Exploring how second grade elementary teachers translate their nature of science views into classroom practice after a graduate level nature of science course. *Research in Science Education (Australasian*

Science Education Research Association), 45(6), 867–888. https://doi.org/10.1007/s11165-014-9447-5

Fuchs, T. T., Bonney, K. M., & Arsenault, M. (2021). Leveraging student misconceptions to improve teaching of biochemistry & cell biology. *The American Biology Teacher, 83*(1), 5-11. https://doi-org.ezproxy.library.unlv.edu/10.1525/abt.2021.83.1.5

Gomez-Zwiep, S. (2008). Elementary teachers' understanding of students' science misconceptions: Implications for practice and teacher education. *Journal of Science Teacher Education, 19*(5), 437–454. https://doi.org/10.1007/s10972-008-9102-y

Leden, L., Hansson, L., Redfors, A., & Ideland, M. (2015). Teachers' ways of talking about nature of science and its teaching. *Science & Education, 24*(9), 1141-1172.

Lederman, J.S., & Khisfe, R. (2002). Views of the nature of science, Form D. Unpublished paper. Illinois Institute of Technology, Chicago, IL.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*(6), 497-521. https://doi-org.ezproxy.library.unlv.edu/10.1002/tea.10034

Lederman, N. G. (2007). *Nature of science: Past, present, and future*. In S.K. Abel & N.G. Lederman (Eds.), Handbook of Research on Science Education.

Lederman, N.G., Lederman, J.S., & Antink, A. (2013). Nature of science and scientific inquiry as contexts for the learning of science and achievement of scientific literacy. *International Journal of Education in Mathematics, Science and Technology*, *1*(3), 138-147.

Kaur, P., Stoltzfus, J., & Yellapu, V. (2018). Descriptive statistics. *International Journal of Academic Medicine, 4*(1), 60.

Maeng, J. L, Bell, R. L, St. Clair, T, Gonczi, A. L., & Whitworth, B. A. (2018). Supporting elementary teachers' enactment of nature of science instruction: a randomized controlled trial. *International Journal of Science Education, 40*(18), 2245-2264. doi: https://doi-org.ezproxy.library.unlv.edu/10.1080/09500693.2018.1528643

Mesci, G. & Schwartz, R. S. (2016). Changing preservice science teachers' views of nature of science: Why some conceptions may be more easily altered than others. *Research in Science Education (Australasian Science Education Research Association), 47*(2), 329–351. https://doi.org/10.1007/s11165-015-9503-9

Metin Peten, D. (2021). Influence of the argument-driven inquiry with explicit-reflective nature of scientific inquiry intervention on pre-service science teachers' understandings about the nature of scientific inquiry. *International Journal of Science and Mathematics Education, 20*(5), 921–941. https://doi.org/10.1007/s10763-021-10197-8

National Science Board, National Science Foundation. (2022). *Science and Engineering Indicators 2022: The State of U.S. Science and Engineering*. NSB-2022-1. Alexandria, VA. Available at https://ncses.nsf.gov/pubs/nsb20221

Okur, M. & Gungor Seyhan, H. (2021). Effect of the argumentation-supported PBL on the determination of pre-service science teachers' misconceptions about the particulate, space, and motion nature of matter. *International Online Journal of Educational Sciences, 13*(4). https://doi.org/10.15345/iojes.2021.04.009

O'Neill, Q. (2011). The importance of understanding the nature of science. *3 Quarks Daily: Science Arts Philosophy Politics Literature.* Retrieved from https://3quarksdaily.com/3quarksdaily/2011/03/the-importance-of-understanding-the-nature-of-science.html

Sarkar, M., & Gomes, J. (2010). Science teachers' conceptions of nature of science: The case of Bangladesh. *Asia-Pacific Forum on Science Learning and Teaching, 11*(1), 1-17.

Schwartz, R. S., Lederman, N. G., & Crawford, B. A. (2004). Developing views of nature of science in an authentic context: An explicit approach to bridging the gap between nature of science and scientific inquiry. *Science Education, 88*(4), 610-645.

Walls, L., Buck, G. A., & Akerson, V. L. (2013). Race, culture, gender, and nature of science in elementary settings. In J. A. Bianchini, V. L. Akerson, A. C. Barton, O. Lee, & A. J. Rodriguez (Eds.) *Moving the equity agenda forward* (pp.

131-151). Springer, Dordrecht.
https://doi.org/10.1007/978-94-007-4467-7_9

Appendix A: Table 1. Sample questions from the VNOS-D+ questionnaire used

Question 1	*What is science?*
Question 2	*What makes science (or a scientific discipline such as physics, biology, etc..) different from other subjects/disciplines (art, history, philosophy, etc..)?*
Question 3	*Scientists produce scientific knowledge. Do you think this knowledge may change in the future? Explain your answer and give an example.*

Appendix B: Table 2. Operationalized Aspects of NOS (Lederman et al., 2002)

Distinction between observations and inferences	Observations are descriptive statements about natural phenomena that are "directly" accessible to the senses (or extensions of the senses). By contrast, inferences are statements about phenomena that are not "directly" accessible to the senses.
Empirical	Scientific knowledge is, at least partially, based on and/or derived from observations of the natural world
Creative and imaginative	Scientific knowledge involves human imagination and creativity. Science involves the invention of explanations and this requires a great deal of creativity by scientists.
Subjective	Scientific knowledge is subjective. Scientists' theoretical commitments, beliefs, previous knowledge, training, experiences, and expectations actually influence their work. Scientists' observations (and investigations) are always motivated and guided by, and acquire meaning in reference to questions or problems. These questions or problems, in turn, are derived from within certain theoretical perspectives (theory-laden)
Social and culture embeddedness	Science as a human enterprise is practiced in the context of a larger culture and its practitioners (scientists) 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. These elements include, but are not limited to, social fabric, power structures, politics, socioeconomic factors, philosophy, and religion.
Tentative	Scientific knowledge is never absolute or certain. This knowledge, including "facts," theories, and laws, is tentative and subject to change. Scientific claims change as new evidence, made possible through advances in theory and technology, is brought to bear on existing theories or laws, or as old evidence is reinterpreted in the light of new theoretical advances or shifts in the directions of established research programs
Distinction between scientific laws and theories	Individuals often hold a simplistic, hierarchical view of the relationship between theories and laws whereby theories become laws depending on the availability of supporting evidence. However, theories and laws are different kinds of knowledge and one can not develop or be transformed into the other. Laws are statements or descriptions of the relationships among observable phenomena. Theories, by contrast, are inferred explanations for observable phenomena.

Appendix C: Table 3. Example of Participant Response and Score (Lederman et al., 2002)

Q #	VNOS D+Question	Example	Score
6	*The model of the the inside of the earth shows that Earth is made up of layers called the crust, upper mantel, mantle, outer core and the inner core. Does the model of the layers of the earth exactly represent how the inside of the earth looks? Explain your answer.*	"I am not sure because, as far as I know, no one has ever seen the inside of the Earth. I think they have a pretty good idea because they have built on the ideas of others to come up with this model."	0, Inadequate information to determine
7	*Scientists try to find answers to their questions by doing investigations/experiments. Do you think that scientists use their imaginations and creativity when they do these investigations/ experiments?* .	"Yes, I think scientists use their imagination and creativity in all parts of their investigation. Many people have to work together to throw out ideas, run trials of many different thought processes and see which leads them to the most likely result based on data and observations collected."	1, Naive responses are not consistent with any part of the NOS aspect
2	*What makes science (or a scientific discipline such as physics, biology, etc..) different from other subjects/disciplines (art, history, philosophy, etc..)?*	"Science isn't just the accumulation of facts/statistics/philosophies. It's an ever evolving process that builds upon knowledge of those who came before. You take what others have discovered and apply your own perspective to it in order to answer and underlying question you have about an observed phenomenon."	2, Transitionals responses are consistent with some, but not all, parts of NOS aspect

Appendix D: Table 4. Scoring breakdown by VNOS D+ Question

Question #	VNOS Question	Count of Rubric Score: 0	Count of Rubric Score: 1	Count of Rubric Score: 2	Count of Rubric Score: 3
1	*What is science?*	5	16	2	0
2	*What makes science (or a scientific discipline such as physics, biology, etc..) different from other subjects/disciplines (art, history, philosophy, etc..)?*	9	11	3	0
3	*Scientists produce scientific knowledge. Do you think this knowledge may change in the future? Explain your answer and give an example.*	5	16	2	0
4a	*How do scientists know that dinosaurs really existed? Explain your answer.*	0	19	4	0
4b	*How certain are scientists about the way dinosaurs looked? Explain your answer.*	4	16	3	0
4c	*Scientists agree that about 65 millions of years ago the dinosaurs became extinct (all died away). However scientists disagree about what caused this to happen. Why do you think they disagree even though they all have the same information?*	7	11	5	0
4d	*If a scientist wants to persuade other scientists of their theory of dinosaur extinction, what do they have to do to convince them? Explain your answer.*	4	15	4	0
5	*In order to predict the weather, weather persons collect different type of information. Often they produce computer models of different weather patterns. Do you think weather persons are certain (sure) about the computer models of the weather patterns? Why or why not?*	10	11	2	0
6	*The model of the the inside of the earth shows that Earth is made up of layers called the crust, upper mantel, mantle, outer core and the inner core. Does the model of the layers of the earth exactly represent how the*	8	13	2	0

	inside of the earth looks? Explain your answer.				
7	*Scientists try to find answers to their questions by doing investigations/experiments. Do you think that scientists use their imaginations and creativity when they do these investigations/experiments?* *If No, explain why.* *If Yes, in what parts of their investigation (planning, experimenting, making observations, analysis of data, interpretations, reporting results, etc.) do you think they use their imagination and creativity? Provide examples.*	3	17	3	0
8	*Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.*	8	14	1	0
9	*After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change? Explain and give an example.*	5	13	5	0
10	*Is there a relationship between science, society, and cultural values? If so, how? If not, why not? Explain and provide examples.*	1	19	3	0
Total Incidences:		69	191	39	0