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Pre-Service Teachers Nature of Science Views After Engaging with COVID-19 as a Socioscientific Issue

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ABSTRACT

This study investigates undergraduate pre-service understanding and views of nature of science (NOS) before and after engaging with a socioscientific issues-based unit based on a the COVID-19 pandemic. The COVID-19 unit consisted of lessons about viruses and bacteria, COVID-19, the spread of disease, and NOS. The data sources consisted of pre- and post-semi-structured interviews and pre- and post-questionnaires. After the unit in post-interviews, most students held transitional views of each NOS aspect (tentativeness, process, society, creativity). However, some students had informed views of tentativeness and process of science and naïve views of society and creativity in science. Pre-service teachers tended to rely on examples from the COVID-19 pandemic when explaining their NOS understandings, which resulted from teaching about NOS with socioscientific issues in a contextualized approach. We discuss the implications of these results for future pre-service teacher training with socioscientific issues.

Keywords: nature of science, pre-service teachers, socioscientific issues

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INTRODUCTION

Consuming scientific information is a daily part of life for most people since the beginning of the COVID-19 pandemic. Understanding this scientific information is necessary to make decisions about the pandemic and other scientific issues. The pandemic is an example of a socioscientific issue, which is a complex and controversial social issue rooted in science but may require answers with more than science alone (Sadler, 2004). Science is embedded in the society it is created in, and scientific understanding and perspectives are influenced by moral, ethical, religious, or political factors. However, textbook science encountered by students in school does not always align with the science experienced in everyday life. Students in a democratic society need to have the skills to consume, understand, and make informed decisions about science information to form their own opinions or perspectives about science or science issues (Presley et al., 2013).

Teaching with issues embedded in society and science helps improve these skills and helps students critically evaluate science information encountered in the real world outside of the classroom (Espeja & Lagarón, 2015). This is a science for citizenship approach, so students are better-informed citizens around the globe about aspects of science within society, which increases scientific literacy skills (Kolstø, 2001). Inherent in working with socioscientific issues (SSI) is an understanding of the nature of science (NOS). NOS instruction can help inform students views and understandings of SSI, and SSI are an effective approach for teaching about NOS explicitly and contextualized (Eastwood et al., 2012; Zeidler et al., 2002). For this approach to be implemented in the classroom, teachers in service and in teacher training programs need more experience integrating NOS and SSI-based instruction (Sadler et al., 2005). Cook and Buck (2013) explored pre-service teachers understanding of NOS as they experienced local campus environmental science issues. Pre-service teachers improved their NOS conceptions, and the researchers concluded that it is important for students to be given a chance to reflect on tenets of NOS while learning with SSI, which allowed pre-service teachers to draw those connections between NOS tenets and their SSI. Another study also used an explicit approach to NOS in combination with an SSI unit about global climate change (Matkins & Bell, 2007). The researchers found improvement in pre-service teachers understanding of both NOS and global climate change along with their decision making about the SSI. NOS is a complex concept therefore, contextualized within SSI-based instruction, pre-service teachers have to opportunity to make real world connections from scientific issues and knowledge to scientific practice. This study aimed to use the COVID-19 pandemic as an SSI to investigate the extent to which pre-service teachers understand the NOS before and after this exposure to the SSI unit. The following research questions guided our study:

1. What were pre-service teachers views of NOS after engaging with COVID-19 as a socioscientific issue?
2. How well do pre-service teachers relate COVID-19 to NOS?

Table 1. Additions and changes to the COVID-19 unit for spring 2021

COVID-19 unit sections	Lessons, discussions, and activities
Spread, classification, and containment of disease	1. *Spread of disease*-Students watched a time lapse of the spread of COVID-19 while discussing how the virus spread compared to other previous epidemics and pandemics. https://covid.yale.edu/innovation/mapping/case-maps/global-time-lapse/ 2. *Risk of contracting COVID*-19-Using the risk calculator, students entered different scenarios into the tool to see what the risk of contracting COVID-19 is in a specific location with a certain number of people. https://covid19risk.biosci.gatech.edu
Vaccines	1. *Vaccine testing and development*-Using the CDC website, we went through the phases for clinical development and approval/emergency approval from the FDA. 2. *Types of vaccines*-We discussed mRNA vaccines compared to viral vector vaccines and the type of each COVID-19 vaccine. 3. *COVID-19 vaccines*-We discussed the Pfizer BioNTech, Moderna, and Johnson & Johnson/Janssen vaccines and presented information from FDA as well as information for the pause of the J&J vaccine in April 2021, which took place during our unit.
Relation of COVID-19 pandemic to NOS	1. *Thinking about science survey*-Students took a 28-question survey showing how they perceive and relate to science as well as any inaccurate conceptions about science. (Cobern, 2001) 2. *Three COVID-19 scenarios*-We presented students with three articles about COVID-19 research accomplishments. Using a discussion board, students discussed which best represented process of science and how they all relate to the NOS.

LITERATURE REVIEW

While scientific literacy has been the goal of science education for years, it is still not clear what exactly scientific literacy entails. Roberts (2007) discusses scientific literacy through two lenses. One lens, vision I, is understanding scientific information, content, and the scientific process. The other lens, vision II, is understanding science in context or situational context. This lens includes political, moral, social, and ethical factors that influence views and understanding of science. We believe that both lenses are needed to understand science issues like the COVID-19 pandemic as the most current example of a socioscientific issue (Sadler et al., 2020). The COVID-19 pandemic has brought science to the forefront of society as we navigate the information presented to the public about the virus and safety protocols. Without a foundational understanding of science content and the process of science, much information about the pandemic could be misinterpreted or misunderstood.

Using the COVID-19 pandemic, as the focal issue, fuses science content and sociocultural aspects that allow pre-service teachers to think about science as integral to everyday life (Sadler, 2009). The use of socioscientific issues, like the COVID-19 pandemic, can help develop scientific literacy skills (Zeidler & Nichols, 2009). Specifically, learning about socioscientific issues have been found to help students develop epistemological understandings of the NOS, gain content knowledge, and increase argumentation and higher order thinking skills (Zeidler, 2014). An understanding of NOS is crucial for pre-service teachers to gain a full perspective for evaluating and analyzing socioscientific issues (Duruk, 2020; Mesci, 2020). An understanding of the epistemology of science is just as important as the science content when learning about controversial, complex, and ill-structured SSI, like the COVID-19 pandemic. For pre-service teachers understanding of and about science, it is crucial to address NOS in an explicit and contextualized manner, with NOS embedded within a science idea, or in this case an SSI (Abd-El-Khalick, 2001; Eastwood et al., 2012; Scharmann et al., 2005). For SSI-based instruction, an understanding of the relationship between science and society is especially necessary. This relationship is crucial to explore with pre-service teachers as they engage with SSI and NOS (Amirshokoohi, 2010, 2016; Seyhan & Okur, 2021a, 2021b). The relationship between science and society and the cultural and social embeddedness of science is the foundation for pre-service teachers seeing the importance of using SSI and understanding NOS.

METHODOLOGY

Setting and Participation

The study took place in an undergraduate science content course for pre-service teachers. In the course, 11 pre-service teachers consented to participate in the study. The course covers K-6 grade science material about physical science, life science, astronomy, earth science, chemistry, and physics. In addition to these fields, we designed a COVID-19 unit over four weeks, with two lessons a week that focused on the science content to support knowledge of the science of the COVID-19 pandemic and the pandemic's relation to NOS. When creating lessons, we used the inquiry constructivist approach to involve pre-service teachers in introducing concepts, moving into activities, discussions, and reasoning about the concepts.

COVID-19 Unit

The unit progressed from scientific information about viruses, bacteria, and COVID-19 lessons into the societal aspects of COVID-19 with the spread of disease and the NOS lessons (Graham et al., 2020). Information from the original unit was updated with current scientific information about the pandemic.

Table 1 gives an overview of components updates and added to the COVID-19 unit taught in the Spring 2021 semester when this study took place. The vaccine lesson was expanded extensively with the creation and distribution of three vaccines being approved for FDA emergency use in the United States.

We also included a guest speaker during the unit with the director of the Smithsonian Science Education Center. The director spoke to the pre-service teachers about a community response guide titled *COVID-19! How can I protect myself and others?* created by the center for use with grades 3-8 to investigate information about the pandemic and steps to help keep you and your community safe (Smithsonian Science Education Center, 2020). The guest speaker provided pre-service teachers with resources to use in their future classrooms with elementary students and ways to get students more involved with their communities to help resolve problems that arise when dealing with complex SSI. With the updated COVID-19 unit, this study examines pre-service teachers' views of the NOS in the context of a socioscientific issue, the COVID-19 pandemic.

Table 2. Views of nature of science

Aspects and questions	Naive	Transitional	Informed
Tentativeness: Is scientific knowledge fixed or tentative? Why and can you give examples?	Only older ideas or discoveries in science are subject to change.	Information about COVID-19 changes based on what we know with new research.	All science information is tentative & subject to change on an understanding of data/ideas at a specific time.
Process: How do you think scientists produce scientific knowledge?	"Doing" science consists of experiments and hypotheses about ideas for discovery.	Science uses scientific method, but sometimes scientific method does not "work," & it is trial & error; or mentions only some parts of scientific inquiry.	The scientific method that is taught in school is different than the process of "doing" science; explains the process of scientific inquiry.
Society: Does society influence science? How and can you give examples?	Society does not directly influence science or does but no example given.	Society could influence science with some offering an example in the context of the COVID-19 pandemic.	Society influences science and science influences society, example provided about COVID-19 or outside example.
Creativity: Do you think creativity plays a part in producing scientific knowledge? Can you give examples?	Scientists only use creativity in experimentation.	Creativity plays a role in science to an extent with questions, hypotheses, experimentation, and data collection.	Creativity is necessary for the scientific process in each component, even data analysis, drawing conclusions, and communicating findings.

Data Collection and Tools

The data consisted of pre/post-questionnaires and pre/post semi-structured interviews. Before the COVID-19 unit, pre-service teachers answered a pre-questionnaire and participated in pre-semi-structured interviews. The questionnaire had 25 short answer questions about the information presented in the lessons, including science content like differences in viruses and bacteria, are viruses living organisms, how viruses invade our cells, how viruses replicate, and how our bodies fight off viruses; and another section about NOS with questions about what science is, how science influences society and vice versa, information changing in science, the process of "doing" science, and how creativity is used in science. The semi-structured interviews followed up, asked more in-depth questions related to the questionnaires, and asked more questions about NOS as listed in **Table 2**. For this study, we focused on the latter portion of the assessment with pre-service teachers views and understanding of NOS in the context of the COVID-19 pandemic. When the unit was completed, the pre-service teachers answered the same questions again for the post measure. After the NOS lesson at the end of the unit, we added questions to the post-interviews specifically about students' views of tentativeness in science, the process of science, the relationship between science and society, and creativity in science. Pre-service teachers were then asked NOS questions about what science is, the goals of science, what is pseudoscience, and what happens during the process of "doing" science. Specifically, we asked when does creativity play a part in the process of science, what do scientists do when their data does not fit their hypothesis or explanation, is knowledge produced from this process fixed or tentative, and how do you think scientists produce this science information. These questions were coded for students views of each aspect of the NOS after our unit using the coding scheme in **Table 2**.

Data Analysis

We had an iterative process of coding the pre- and post-questionnaires and interviews. Pre-service teachers' questionnaires and interviews were analyzed using the constant comparative method by extracting common patterns and themes in the data (Strauss & Corbin, 1998). After that, we went back and coded students' answers refining our codes accordingly. The authors checked for reliability by coding 50% of the data, and it was over 85%. All disagreements were settled by discussion. For the views of NOS in the post-interviews, we coded using three levels of understanding (naïve, transitional, and informed) adopted from Eastwood et al. (2012) and Lederman et al. (2002).

RESULTS

For the pre-questionnaire and pre-interviews, there was no to little understanding from pre-service teachers about NOS. All pre-service teachers received either no score or naïve views for every aspect of NOS. Most left questions blank, stated they did not know, or attempted to answer with naïve understanding of NOS. Therefore, we decided to use the post-questionnaires and post-interviews to investigate students' NOS views further. These two data sources were iteratively coded producing codes for the tentativeness of science information, the process of science, the relationship between science and society, and creativity in science (**Table 2**). Examples of pre-service teacher responses for each level of coding and each aspect of NOS can be found in **Table 3**. Due to our small sample size, responses were not present for all of the coded categories in the post responses like the naïve view of tentativeness and the informed view of society and creativity in science.

The results showed all pre-service teachers held a transitional or informed view of the tentativeness of science after the unit, with eight responses falling in the transitional stage (**Table 4**). When asked to give examples about tentativeness and changing information in science, nine pre-service teachers presented examples related to COVID-19, like initially being told not to wear a mask then to wear one, decreasing social distancing from six feet to three feet, COVID-19 living on surfaces then being shown it does not, and how long COVID-19 antibodies are active in the body. Still, two pre-service teachers used examples of when scientists thought the earth was flat or the center of the universe or Pluto no longer categorized as a planet and how those explanations were abandoned or changed with new evidence. These pre-service teachers carried these ideas into science topics outside of COVID-19.

Six of the pre-service teachers held transitional view of the scientific process, with one pre-service teacher holding a naïve view and four pre-service teachers improving to a more informed view (**Table 4**). When asked about how scientists produce scientific knowledge, three pre-service teachers described learning about the scientific method in school. One pre-service teacher stated, "I do not think they follow the scientific method we were taught for every single thing." In addition, five pre-service teachers described their view of the science process as trial and error, with one describing science as "a trial-and-error process of experimentation until they find something that works." Another stated "a lot of trials take place, and they analyze their

Table 3. Examples of pre-service teachers views of NOS

Aspects and questions	Naive	Transitional	Informed
Tentativeness: Is scientific knowledge fixed or tentative? Why and can you give examples?		"Definitely tentative like with COVID-19 how they changed social distancing from 6 feet to 3 feet"	"I think it is always subject to change in like the scientific world … back a long time ago scientists thought the Earth was flat and only part of the ocean has been discovered now … I think there's always more to be discovered everyday"
Process: How do you think scientists produce scientific knowledge?	"I think about experiments because from a young age we are taught scientists do experiments, get a result, and create a hypothesis and the scientific method"	"Scientists start with a hypothesis or a theory and experiment then analyze their results over and over again like trial and error to get consistency for their results and to be accurate"	"The scientific method that we learned when we were little is not really an accurate representation of science and our scientist work … It definitely opened my eyes to see how robust and complex science is because I think in elementary school, everything's really dumbed down for us."
Society: Does society influence science? How and can you give examples?	"I don't know if society influences science directly but I think people influence other people in society about science."	"I think society really pushed scientists and the world of science to get the [COVID-19] vaccine out"	
Creativity: Do you think creativity plays a part in producing scientific knowledge? Can you give examples?	"To an extent, there is a certain aspect where you are not supposed to have creativity, and everything is supposed to be standard and subjective"	"In asking questions and creating new ideas in order to get closer to the answer I think you have to be creative in that aspect" "to come up with a hypothesis and design an experiment"	

Table 4. Views of NOS components

	Naive	Transitional	Informed
Tentativeness	0	8	3
Process	1	6	4
Society	4	7	0
Creativity	6	5	0

trials until they come to their results." Three mentioned experimentation and replication as part of the process and when asked how scientists produce knowledge one pre-service teacher answered, "classical experimentation, you know science that comes out were probably tested in some way and you may not even realize how but it goes through a lot of experiments before reaching the public." Last, two pre-service teachers discussed the peer review process to distribute information responding with "peer reviewed journals are a big thing because scientists will publish information they found or data they are finding, but it has to be reviewed by a number of professionals before it is accepted, which makes a lot of sense."

While 10 pre-service teachers improved their naïve understandings, only four reached an informed view of the process in science. Some continued to hold on to misconceptions about process of science following a set of steps or not being subject to revision.

When asked about the relationship between science and society, four pre-service teachers held naïve views, and seven held transitional views (**Table 4**). All 11 pre-service teachers interviewed agreed that society influences science, but the reasoning and examples of influence varied. A typical response was that society influences what is socially cared about most in science at a particular time. Only three pre-service teachers gave examples when asked to explain further, and all examples were related to COVID-19 or the COVID-19 vaccine. Pre-service teachers learned about the social embeddedness of science in the context of this unit. Still, there are many different science issues prevalent and controversial in society showing the complex relationship between science and society did not transfer outside of the idea of COVID-19. This study introduced this relationship and provided a context to understand this concept further with the COVID-19 pandemic. However, while there was some improvement (**Table 4**), no pre-service teachers came to fully understand this relationship better in the post-interviews, with no pre-service teachers showing an informed understanding for the societal aspect of NOS.

For creativity, one question pertained to creativity in producing scientific knowledge, and the second question focused on creativity in the science process after data collection. We asked pre-service teachers if they thought creativity played a part in producing scientific knowledge, and 11 students agreed it did, but in different ways. When probed further about the role of creativity, only six students provided examples of creativity in the scientific process, with four stating it plays a part in creating hypotheses and research questions and two explained how it plays a role in the creation of experiments. All explanations were related to the process before or during data collection. Six pre-service teachers held naïve views of creativity in science, and five held transitional views where they believed creativity happened in stages other than just experimentation but not all steps (**Table 4**). For the second creativity question, we asked what they think a scientist does if their data does not fit their hypothesis or explanation. Four pre-service teachers thought scientists kept the data for the future and it could possibly fit another hypothesis in the future. One pre-service teacher stated, "I think they would hold on to it for a bit because what if they can solve something else in the future… maybe the idea is good, but they have to change it a little bit." Three pre-service teachers that answered thought scientists would rethink their hypotheses based on what the data showed, with one stating, "They have to rethink what their hypothesis is and with the new information take it and learn from it. I think they need to take that information and rethink what they are doing." Other students were unsure of what a scientist would do in this scenario.

DISCUSSION AND CONCLUSION

This study reveals that pre-service teachers did show improved understandings of the NOS in the context of the COVID-19 pandemic. Some areas of NOS were improved more than others like the tentativeness of scientific knowledge and the process of science. Using COVID-19, as a socioscientific issue, and teaching NOS in the context of this issue helped pre-service teachers further their understanding of science.

While views of the NOS improved in this context, pre-service teachers did not always provide examples or transfer these concepts into other topics or issues about science outside of the COVID-19 pandemic. When asked for examples to support their answers, pre-service teachers provided examples related to COVID-19, which was expected due to the NOS being taught in the context of this socioscientific issue. While pre-service teachers improved their knowledge of creativity in science, all explanations and examples were described before or during data collection. For future studies, it would be beneficial to ask participants about creativity in each stage of the scientific inquiry process and have them elaborate. This could allow for a more robust analysis of their views of creativity throughout the scientific process of producing knowledge instead of the process as a whole and a better understanding of what the term creativity means to the participants in science (Abd-El-Khalick, 2006; Lui & Lederman, 2002).

Still, we saw some transfer of this NOS knowledge into other science ideas with the tentativeness of scientific knowledge. This supports the notion that NOS needs to be taught with many science ideas, or socioscientific issues, for students to develop a full understanding, contextualized and decontextualized. Bell et al. (2016) and Leden et al. (2020) investigated NOS understandings across various levels of (de)contextualization and found that pre-service teachers showed significant improvements. Even more so an explicit reflective approach to NOS instruction has shown more meaningful understandings than rote memorization of NOS tenets (Bilican et al., 2015). However, for this study, pre-service teachers were introduced to NOS only in the context of the COVID-19 pandemic explicitly. In the future, pre-service teachers would benefit from a combined approach exploring NOS implicitly and decontextualized before moving into NOS explicitly and in the context of a socioscientific issue. This combination has potential to promote a fuller and more effective understanding of NOS (Abd-El-Khalick, 2001; Bell et al., 2016; Brickhouse et al., 2000; Clough, 2006).

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