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Research Article

Pre-service mathematics teachers' views of nature of science in the context of COVID-19

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ABSTRACT

A framework for K-12 science education (National Research Council [NRC], 2012) supports science learning on social and political issues to make informed decisions and solve problems. Socio-scientific issues have been considered as a context to teach characteristics of nature of science (NOS). This study is a qualitative study in nature to examine how pre-service mathematics teachers define science and address different aspects of science and scientific literacy in the context of coronavirus (COVID-19). Data sources included written reports and reflections on basic science-related questions. Responses from 50 pre-service mathematics teachers were analyzed through thematic analysis. The results indicated that pre-service mathematics teachers defined science as a product in the form of systematic knowledge, fact or theories-laws-models, and they provided informed or partially informed views on empirical, sociocultural, tentativeness, and subjectivity aspects by referring to cognitive, developmental, and sociocultural dimensions of science literacy. Pre-service mathematics teachers' definition of science as accumulated knowledge was not aligned with their desirable views on aspects of NOS. The study suggests possible implications for further studies.

Keywords: views, beliefs, nature of science, mathematics teachers

INTRODUCTION

Teachers' beliefs are related to teachers' planning and pedagogical decisions, their teaching practices, and their students' learning (Pajares, 1992). Teachers' beliefs determine what to teach or what not to teach, how to communicate information, and how to facilitate and assess student learning (Fives & Buehl, 2017; Sengul et al., 2021). Teachers' beliefs have been explored focusing on domain-general beliefs such as education, teaching and learning and domain-specific beliefs to address views of science or science teaching and learning or science literacy (Van Driel et al., 2007). Teachers' beliefs about nature of scientific knowledge have been essential to understanding how they conceptualize how scientific knowledge develops and how learning occurs (Lee & Tsai, 2011; Tsai, 2008). In other words, teachers' beliefs involve their understanding of the epistemic nature of a discipline referring to their views of nature of science (NOS) and how to teach and learn science.

Lederman (1992) indicates that teachers with naïve beliefs define scientists' and teachers' work as to find the correct and absolute answers to the problems or to teach how to prove the formulas of physical laws through step-by-step laboratory procedures. These teachers are usually exposed to traditional or teacher-centered instruction that science is presented as static knowledge or rhetoric of conclusions (Abell & Smith, 1994; Scwab, 1960). However, as Duschl and Grandy (2013) suggest, the focus on 'doing science' addresses science teaching and learning through inquiry approach in which learners engage with phenomena through experiments, demonstrations, and observations. These alternative approaches to science teaching and learning aim to establish the cognitive, social, and epistemic models of learning for both scientists and students, and their goal is "science for all" (Duschl & Grandy, 2013).

A framework for K-12 education (National Research Council [NRC], 2012) suggest that individuals should develop some appreciation of science with adequate scientific and technological knowledge to carefully use their knowledge to make informed decisions related to scientific issues in their everyday lives. Recent reform documents on science education (NGSS Lead States, 2013; NRC, 2012) support scientists and teachers to emphasize scientific practices and characteristics of science along with core scientific concepts to enhance scientific literacy (Lederman & Lederman, 2014). This emphasis on scientific literacy refers to the application of scientific knowledge through processes such as observation and experimentation with sufficient language literacy, critical reasoning skills, and understanding of social, cultural, economic, and political aspects of doing science (e.g., the epistemic NOS) (Cavagnetto, 2010; Duschl, 2008; Kucer, 2009). Individuals are suggested to be active participants of science-related issues in society to find the solutions to problems related to science and society and promote their participation in authentic experiences such as questioning, exploration, and guidance.

Lederman (2007) defines NOS as epistemology of science, referring to what science is and how it works as well as the values, assumptions, and beliefs scientists use to develop scientific knowledge. NOS is often debated among philosophers of science, historians of science, and science educators (Abd-El-Khalick, 2013; Erduran et al., 2019; Hodson & Wong, 2017; Irzik & Nola, 2014; Lederman, 1992; Matthews, 1998). These NOS approaches address different philosophical perspectives but include common generalities. The main characteristics of science is defined in these studies as in the following:

(a) scientific knowledge is reliable and tentative (subject to change), but durable as well,

(b) scientific knowledge is empirically based, and no single method can be used to do science,

(c) creativity and imagination play a part in the development and use of scientific knowledge,

(d) the results of the scientific research are influenced by subjectivity- individual scientific perspectives (related to theory) as well as scientists' values, knowledge, beliefs and prior experiences, and

(e) sociocultural-embeddedness defines how society- cultural, political, and economical factors influence the development of scientific knowledge.

These elements of science also interact with each other in different ways. For example, the empirical aspect of science serves as a basis for the tentativeness of science; scientific knowledge develops through the data from the experimentation and interpretation of data by using personal subjectivity, scientific perspectives (theories), and social and cultural needs.

Teachers' understanding of NOS has not improved through simply 'doing science' or engaging in hands-on, inquiry-based activities (Abd-El-Khalick & Lederman, 2000; Akerson et al., 2009; Clough, 2006; Oliveira et al., 2012). This kind of implicit approach to NOS has been ineffective to develop adequate understandings of NOS. Abd-El-Khalick and Lederman (2000) reported that using history and philosophy of science instruction as an explicit approach to teach NOS improved learners' views of NOS. The authors suggested that using explicit approach was more effective than using inquiry-based laboratory activities to implicitly teach NOS. In Schwartz et al.'s (2004) study, pre-service science teachers' understanding of NOS improved through actively participating in scientific research activities and reflecting on NOS in the context of their authentic science experiences. In a recent study, Edgerly et al. (2022) utilized explicit-reflective NOS instruction in a professional development course and found that elementary in-service teachers developed strong understandings of NOS, and their implementation of NOS was parallel to their views. Using contextualized science tasks supported teachers' understanding and enactment of characteristics of science.

Using a historical case aims to overcome the usual learning problems of teaching about NOS. One of the public issues as an historical outbreak was the epidemic of severe acute respiratory syndrome (SARS) in 2002-2003. Wong et al. (2007) used SARS epidemic as a context for teaching the aspects of NOS. The authors found that using a well-documented history of SARS in an explicit teaching approach to NOS promoted student teachers' understanding of epidemic's close relationship with technology and society. In recent years, science reports and debates reflect that coronavirus-19 (COVID-19) also provides the examples of teachable aspects of NOS. Demirdogen and Aydin-Gunbatar (2021) suggested that media reports on COVID-19 promoted high school students' views of NOS on tentativeness, empirical-embeddedness, subjectivity, and role of inference aspects. Shi (2022) discussed the subjectivity included in studying COVID-19 that scientists' prior knowledge and beliefs played a role in the use of multiple methods, technology, and creativity and imagination. For example, different researchers did research on different natural hosts of coronaviruses such as bats and snakes to identify DNA structure and make inferences. Elsner et al. (2023) discussed the use of modelling in the context of COVID-19 through using descriptive and mechanistic models on handwashing, computer simulation to represent infection curve, and mathematical model of spread of virus. In another report, Bergman (2022) aimed to explain how COVID-19 pandemic process could be used to explicitly refer to different aspects of NOS in the classroom. His lesson emphasized the development of multiple coronavirus vaccinations by different nations to address the use of variety of methods in science, but he emphasized that there might be common values and standardized procedures to follow in specific disciplines. Another activity related to COVID-19 was compulsory mask-wearing, whereas he aimed to explain that more information about the virus made scientists change the idea of wearing masks. Bergman (2022) stated that dealing with a social scientific issue could help students and teachers argue about natural phenomena with empirical evidence that might lead changes in their views.

Teachers' views of NOS have been an important aspect of teacher epistemology and closely related to the goal of science education and scientific literacy. Previous research (Bergman, 2022; Demirogen & Aydin-Gunbatar, 2021; Elsner et al., 2023) focused on the activities related to COVID-19 to emphasize the characteristics of NOS. These studies explained the types of the activities for specific elements of science such as empirical or tentativeness aspects. However, teachers' and learners' views on NOS become important to understand what and how they think on socio-scientific issues from an interdisciplinary perspective. As previous research mainly focused on science activities on COVID-19, the evidence from teachers' and learners' views of NOS is missing. This study aims to investigate whether explicit NOS instruction by using a contextualized case is effective in promoting pre-service mathematics teachers' understandings of key elements of NOS. Pre-service mathematics teachers were conveniently chosen to understand non-major science college students' approach to scientific and societal issues such as epidemics. The participants took an introductory science and mathematics education course addressing scientific inquiry and NOS. The study aimed to understand pre-service mathematics teachers' views of NOS in the context of COVID-19. The study's purpose is to answer the following question: What are pre-service mathematics teachers' views of NOS in the context of COVID-19?

METHODS

This study had a constructivist perspective (Denzin & Lincoln, 2008) to develop in-depth understanding of how pre-service mathematics teachers' views of NOS was constructed through qualitative methods including class discussions, open-ended survey responses, and written artifacts. This study took place at a large research university in the northwest region of Turkey during a semester-long orientation to science and mathematics education course. The course met for two hours each week within a 13-week semester: First six-week of the course emphasized science education topics; other portion of the course addressed topics related to mathematics education and integration of science and mathematics education. The orientation to science and mathematics education course was the first education course for their department; they also took introductory science and mathematics courses (such as physics or mathematics courses) from faculty of natural sciences in their first two years. There were 61 pre-service mathematics teachers enrolled in the course as second-year college students (21-23 ages) in the faculty of education. These pre-service mathematics teachers were conveniently asked to participate in the study; a total of 50 students (six males, 44 females) from the course consented to provide data for the study. These students completed a consent form to indicate their agreement to respond to the questions appropriately.

The author was both the researcher and instructor of the course. The instructor as science educator taught the course by addressing main science education content in six weeks: inquiry-based instruction, NOS, scientific practices, and literacy issues. During the course, the instructor asked students to read some articles, discuss related questions with the instructor during the whole-class discussions, watch sample science and mathematics related activity videos, reflect on their understandings, and explore how to integrate science and mathematics in a project about a science related problem. **Table 1** provides the sample list of suggested articles to read during the course.

Table 1. Content of the course for science education

Week	Topic	Related literature and readings
1-2	Science education	Bybee (2010, 2011)
3-4	Inquiry-based education	Johnson and Johnson (1999); Wilcox et al. (2015)
5-6	Nature of science	Peters (2006); Wong et al. (2009)

Table 2. Data sources and timespan of data collection

Data source	Timespan
Invitation to the study	First week
Responses on reflection questions	Each week during the semester
Report on a science related movie analysis	Last week
Report on a science related investigation	Last week
Question-related to COVID-19	Last day of the class

Assignments of the course aimed to promote pre-service mathematics teachers' understanding of NOS. Each week, pre-service mathematics teachers responded to some fundamental questions regarding their views of science and science literacy. After the class discussions on suggested readings, each week, pre-service teachers asked to reflect on different questions such as, "What is science? What are the main characteristics of science? What can scientifically proficient students do? Why is scientific literacy important? Are you aware of what the enterprise of science is?" These questions came from the readings (**Table 1**), or popular news related to science literacy such as Siegel (2017).

In addition, NOS is explicitly discussed in the course through referring to SARS epidemic investigations. Students discussed empirical, tentative, subjective, creativity, inferential, and sociocultural aspects of NOS referring to a documentary and science education article on SARS epidemic (Wong et al., 2009). Students were also expected to analyze a science-related movie and wrote a report to explain how NOS was integrated in the story. Then, they designed a science-related inquiry-based investigation, and they reported how they integrated the elements of NOS. Their written reports were used to assess how pre-service mathematics teachers understood and emphasized the aspects of NOS. At the end of the course, students were asked to consider the recent epidemic, COVID-19, issue and respond to the following questions: Which elements of NOS can be explained in the battle against coronavirus-19 (COVID-19)? How does scientific work contribute to the solution to the problems that occurred due to the outbreak of COVID-19? Students' written reports and reflections on these questions were utilized as data sources. **Table 2** provides the list of data sources and their collection timespan.

Data analysis required the use of qualitative methods to analyze written artifacts and pre-service teachers' reflections on science-related questions. The researcher utilized inductive thematic analysis (Braun & Clarke, 2006) to develop codes and categories into themes from the students' responses addressing their views of science. The reflections and written reports were reviewed to identify participants' insights about definition of science, aspects of science, and science literacy. These themes were derived from the previous research: "Definition of science" theme included three categories consistent with the results from Abell and Smith (1984) and Bloom (1989). "Views of science" theme addressed the results from McDonald (2010) and Schwartz and Lederman (2008). Different aspects of NOS (creativity and imagination, empirical, tentativeness, subjectivity, socio-cultural-political embeddedness) were addressed in this study, and they were coded on a continuum as described in McDonald (2010): naïve, limited, partially informed, or informed in which naïve views referred to non-existing views, limited views referred to poor understandings, and partially informed or informed views referred to developed understandings of NOS. "Views of science literacy" theme was categorized based on Kucer's (2009) dimensions including four categories: linguistic, cognitive, developmental, sociocultural. **Table 3** represented the codes emerged from the data and developed to categories and themes by the guidance of previous research.

The researcher used the codebook presented on **Table 3** to identify how pre-service mathematics teachers addressed the definition of science, views of science, and science literacy. The coding of written reports and reflections was done twice by the researcher (as the instructor of the course): First, the researcher did the coding individually. Then, the researcher asked another science educator to use and apply the codebook on a sample student reflection: two researchers compared their coding, and inconsistencies were discussed and

Table 3. Codebook: Categories and themes developed by previous research

Theme	Category	Code
Definition of science (Abell & Smith, 2001; Bloom, 1989)	Product	Disciplinary/interdisciplinary; facts; gaining through new findings, systematic knowledge; theories, laws, & models
	Process	Explanation of natural phenomena; study of natural environment; prediction
	Human endeavor	Way of knowing
Views of science (McDonald, 2010; Schwartz & Lederman, 2008)	Creativity & imagination	Naïve: Non-existing understanding Limited: Poor understanding Partially informed: Desirable knowledge Informed: Desirable knowledge
	Empirical	
	Tentativeness	
	Theory-ladenness	
	Sociocultural	
Views of science literacy (Kucer, 2009)	Linguistic	Role of language
	Cognitive	Comprehension/science concept
	Developmental	New knowledge/technology
	Sociocultural	Depending on social, cultural, political, & economic factors

resolved. During the second round of analysis, the researcher checked the consistency between the codes, categories, and themes across all data sources based on the codebook. The results of the qualitative analysis were presented by choosing sample quotations for each theme and category. The results were also provided in the form of descriptive statistics to report the frequency of participants' responses for each category.

FINDINGS

Pre-Service Mathematics Teachers' Views of Nature of Science

Results from the questionnaire on pre-service mathematics teachers' views of NOS provided three themes: definition of science, views of science, and science literacy. Each of these themes is described below.

Definition of science

The results showed that participants' views of NOS included their definition of science in three categories: describing science as a product, a process, and human endeavor (**Figure 1**). Participants approach science as a system of knowledge or a product and their responses addressed

(a) discipline,

(b) facts,

(c) gaining new findings,

(d) systematic knowledge, and

(e) theories-laws-methods.

The complexity of participants' responses was varied. For example, participant (1) stated:

> "Science is based on our understanding of natural sciences like physics, biology, and chemistry … Scientific work is everything to solve the problems caused by outbreak of COVID-19. We have biology and chemistry for solving the main problem, which is a virus outbreak. We have social sciences to help public. We have psychology to help people in these lonely days and help them get over the social limitations, which causes the loneliness."

This definition aimed to explain the connection between the problem and disciplinary science and address the function of different disciplines in the case of a disease. Participant (4) addressed science as a systematic knowledge and stated:

> "Science is a systematic knowledge about the physical world … Scientists try to identify this virus, and they explain and predict, they need to evidence to take more steps. Scientific work is done through both finding the virus and its solution like vaccination."

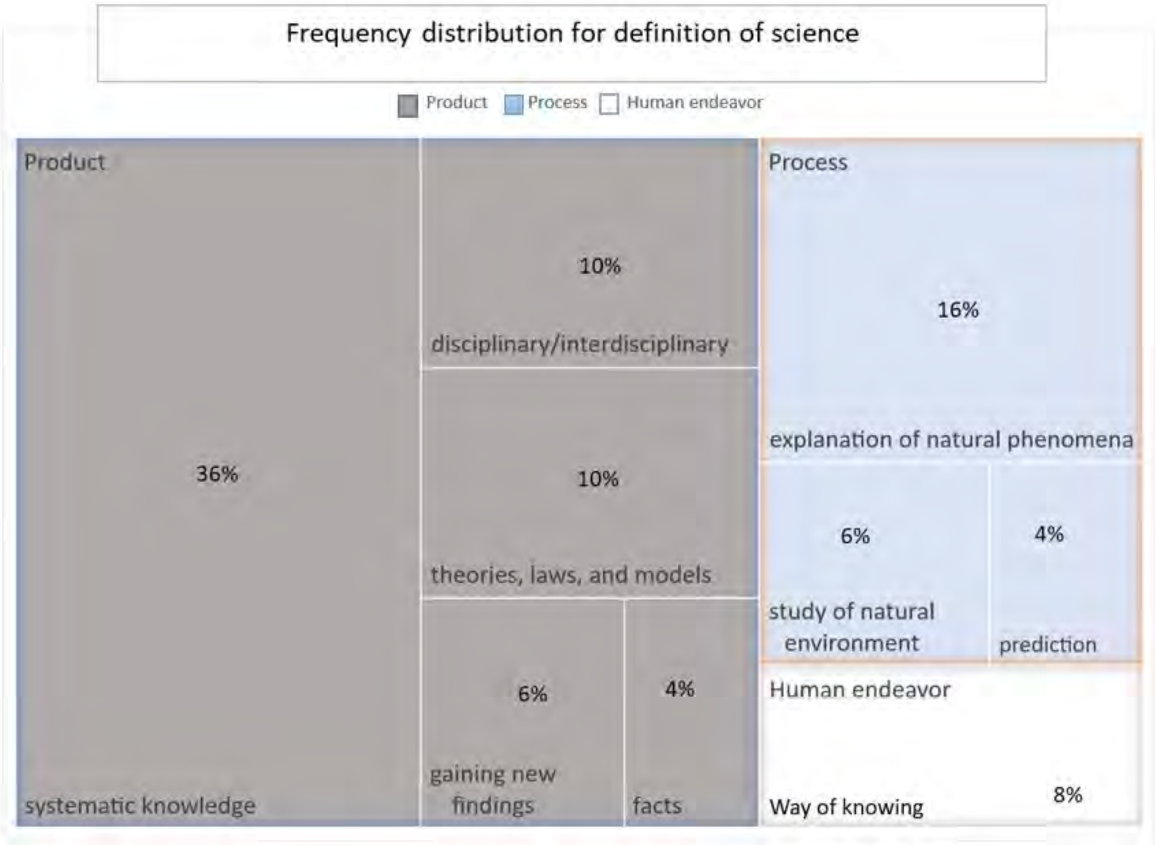

Figure 1. Percentage of codes for definition of science (Source: Author's own elaboration)

In this statement, participant (4) emphasized science as a method followed an approach to predict and explain scientific phenomena. This description of science addressed systematic knowledge as accumulated through experimentation and observation.

Participants also referred to knowledge as the product of scientific enterprise involves valid, logical, and consistent explanations. For example, participant (19) stated:

> "Science students should understand the relationship between explanations and the way scientific knowledge is constructed and applied. Scientists' work aims to make an explanation using theories and models and their relationship with the results."

This statement defined the science as a body of knowledge addressing theories-laws-models.

In "process" category, participants addressed science as

(a) explanation of natural phenomena,

(b) study of natural environment, and

(c) prediction (**Figure 1**).

Participants provided combined responses. For example, participant (19) addressed science as an explanation of natural phenomena and stated:

> "One of the elements of NOS is predictability, which can be explained in the battle against COVID-19. COVID-19 is a unique experimental subject. No one has ever faced this virus before. Scientists describe the phenomenon, work to explain and predict … Scientist study to prevent the spread of the epidemic with the help of mathematics and science. They try to predict future scenarios by using graphics."

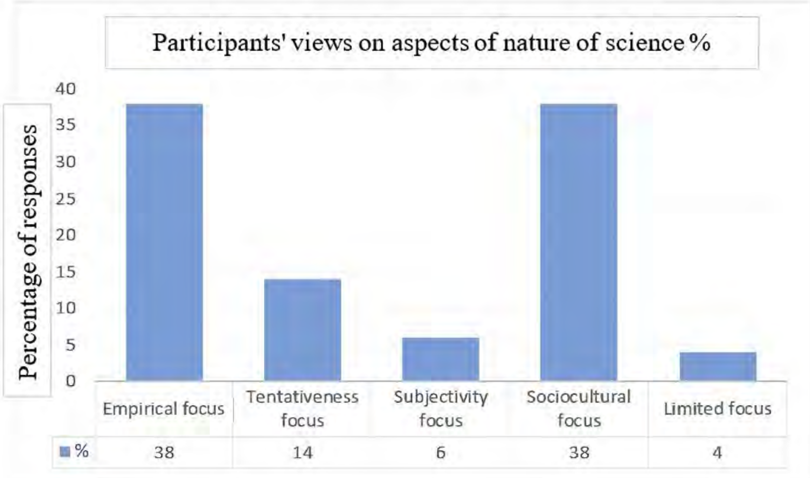

Figure 2. Percentage distribution of participants' views of science (Source: Author's own elaboration)

Participant (19) discussed the aim of science as the explanation of natural events or incidents through considering the results of experiments and integrating mathematics into science. This statement emphasized the relationship among "explanation of natural phenomena, study of natural phenomena, and prediction."

In "human endeavor" category, four participants defined science as human production influenced by individual thinking and learning including scientific explanations, theories, laws, norms, and social and cultural practices. Participant (38) emphasized the science as a human endeavor while emphasizing subjectivity aspects of science and stated:

> "Science is described as a way of knowing the values and beliefs at the origin of scientific knowledge or the development of scientific knowledge. Science explains what virus is and how it is spread in the world. Science uses the element of the nature of observation. There is objectivity and subjectivity in science among scientists ... Scientific work have some contribution about how to protect from COVID-19... Most scientists put forward different hypotheses. All the attempts may contribute to the solution to the problems."

This definition addressed scientific knowledge as a human production influenced by the theoretical perspectives, personal beliefs, and cultural values within a context such as COVID-19.

Views of science

The results showed that participants defined the characteristics of science focusing on informed or partially informed empirical, tentativeness, subjectivity, and sociocultural aspects, and they provided some limited views (4%) (**Figure 2**). The participants used combinations of different aspects of science. Each focus was described below:

Empirical focus: The results showed that 38% of the participants discussed the empirical aspect of science. They emphasized the knowledge derived from human assumptions, prior knowledge, formulation of hypotheses, observations and experimentation, and other science process skills such as calculation, measurement, and collaboration. Clough and Kruse (2019) discussed that the most common misconception about science was that scientists followed a step-by-step scientific method when conducting research. The researchers argued that scientists utilized variety of methods including the exploration of the phenomena, using the existing knowledge and resources, experimentation, modelling, individual preferences, and imagination and creativity. For example, participant (29) provided informed views on empirical aspect of science and stated:

> "Science is subject to change and based on evidence ... Science is a way of knowing and better understanding the natural world through investigations and a human endeavor. It is built on observation, collecting evidence and explanations. It is constantly open to revision and change. They can do problem-solving and calculating, which makes them engage in analyzing and

> interpreting data and using mathematical computational thinking. Therefore, all new problems i.e., COVID-19 can be observed and thanks to science new beneficial information about them can be gathered with observation and empirical evidence …"

In this statement, participant (29) emphasized experimentation and observation with the use of scientific practices such as data collection and analysis. In addition to empirical aspect, participant (29) referred to science as there was no single method, including process skills and subject to change.

Participant (36) indicated partially informed views on empirical aspect of science. She stated:

> "Science is the scientific explanation of events in nature. COVID-19 is a virus that has affected the world, so scientific studies are carried out. Scientists try to treat this disease … They can observe how quickly the virus spreads and what kind of symptoms it has. Firstly, observation is made, questions are asked, hypothesis is created, experiment is done and finally a conclusion is reached … Scientists make logical explanations of nature through following these steps. Scientists should be interpreting, evaluative, solution-oriented, and versatile thinkers to overcome the epidemic. The necessity of having a multi-faceted perspective is related to NOS. Scientific evidence should be used for treatment for COVID-19. Finally, using their creativity and imagination, scientists can find methods against the COVID-19 outbreak."

This statement of participant (36) indicated partially informed views on empirical aspect of science combined with partially informed views on scientific method, tentativeness, and creativity and imagination. This participant (36) described creativity and imagination as embedded to empirical aspect of science. In addition, participant (2) provided partially informed views on empirical aspect of science combined with sociocultural and subjectivity aspects of science. He stated:

> "Science is a systematic knowledge about the universe to develop scientific knowledge via testable explanations and predictions. Science has some elements such as the objectivity, verifiability, neutrality, reliability, precision, accuracy, abstractness, and predictability. In COVID-19, we encounter these elements of science. All scientists regardless of their nationality or religion make scientific research to find a cure for this disease. Thus, we see that scientific research are universal and neutral. Scientists are analyzing and interpret the data and they choose another step according to these analyzes. This shows us that science is progressive. Another element of NOS we encounter in this pandemic process is the predictability. Analyzing the situations, scientists can predicate some dangers and warn the people."

In this statement, participant (2) discussed the empirical aspect of science involving predictability, testing, data collection and analysis, and explanations even though the participant refers to subjectivity and sociocultural aspects of science as objective and universal.

Tentativeness focus: There is another myth about scientific knowledge that science is defined as absolute proven truth. However, new questions and problems lead to new research approaches to revise or replace the existing knowledge. Scientific knowledge is subject to change through well-designed systematic studies; it cannot change easily since it is durable. The findings indicated that only 14% of the participants emphasized the tentativeness of science (**Figure 2**). Only one participant indicated informed views, others (six pre-service teachers) were in partially informed level. For example, participant (19) stated:

> "Through individual and collective effort, people use scientific knowledge to develop new technologies and provide solutions about societal issues. Scientific products are interconnected with the processes that those products are built. Scientific products are directly related to their applications: a new product may lead to new applications and may support the development of new products. People from different nations or cultures contribute to the development of scientific knowledge. Scientific knowledge relies on observation, experimental evidence, and rational predictions. Scientific knowledge has a tentative character. Observations are theory laden."

This statement presented informed views on tentativeness discussing science as tentative, but durable character. In another case, participant (31) provided partially informed views on tentativeness and stated:

> "Science … works with technology and make our lives easy. It also changes, it is non-dogmatic … when there is new enhancement, it can change."

Participant (31) explained her views on tentativeness by referring to technology and its impact on science through new developments.

Subjectivity focus: Most participants defined science as a product or process; less participants focused on science as a human endeavor. Science does not only involve the results of experiments and well-established theories and laws; it also involves the subjectivity in conducting the research. Science is influenced by previous knowledge, beliefs, values, and theoretical perspectives of scientists. The results showed that only 6% of the participants emphasized the subjectivity of scientific knowledge. Three students provided partially informed views on subjectivity aspect combined with empirical and tentativeness aspects (**Figure 2**). For instance, participant (42) stated:

> "Science is a way of understanding the nature. Scientists need to ask some basic questions like how or why. Also, … testing, observation and experiments are considerable … Science is repeatable. Science includes some crucial elements, which are creativity, imagination, evidence, observation, inference, subject to change, culture, society and non-dogmatic. Culture and society have a major role in the spreading the virus. There are differences of how to approach science by different scientists in different countries, the results change country to country … Scientists from all around the world can cooperate each other and discuss about this virus and how to destroy it."

This statement indicated participant's (42) views on subjectivity of science. She discussed that different researchers might have different approaches and perspectives in the solution of a problem, and they came up with different results due to these different assumptions. Another participant (participant (48)) stated:

> "Talking about collaboration and competition among scientists. Although COVID-19 was a global problem, governments considered the national interests of countries at this point, not global … I see from outside countries and big companies conduct their own research. The other issue is about honesty. In our country, we cannot provide an environment of trust among the community and government. I think there are some reasons that are unrelated to science. I think this is also related to a lack of collaboration. There are a lot of research and so a variety of opinion about COVID-19. Some ideas conflict and people are confusing about which one they should believe …"

In this statement, participant (48) emphasized the significance of collaboration and competition among scientists and researchers in the process of solving a problem. He also referred to the interest, trust, and honesty as factors influencing the results of the studies.

Sociocultural focus: The results also presented that 38% of the participants emphasized the social and cultural embeddedness of the scientific knowledge (**Figure 2**). Participants discussed how the virus spread and influenced the society in a variety of ways including historical, social, and psychological factors. For example, participant (32) emphasized the significance of social-cultural embeddedness and stated:

> "When we first encounter COVID-19, it is affected by culture and society; for example, Chinese cuisine may make a way for this disease so the process can be affected by social and cultural embeddedness. However, a lot of theories can occur at the end of this COVID-19 process; people of future can benefit from this process and its findings for different processes. Because science is affected by historical and social process."

Additionally, participant (35) also addressed the factors that might influence the development of scientific knowledge and stated:

> "Social and historical factors play a central role in science because it progresses by gathering the right information and it is tentative in COVID-19 situation … Since science and technology are not

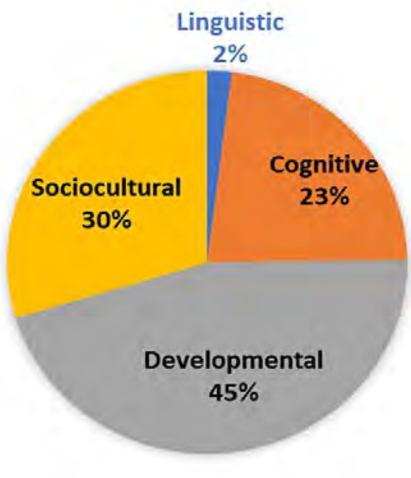

Figure 3. Percentage distribution of participants' views of science literacy (Source: Author's own elaboration)

> the same, however they impact each other that is why collaboration of two scientists resulted in finding other resources. Because science is collaborative,.. information collected and shared without competition that made our lives easier. Before COVID-19, … using the information contained SARS and its important properties have been researched beforehand to proceed … to make the vaccine easier to find fortunately. It is a claim that accurate record keeping, and previous outbreaks taught how society should behave … before people suffer from the psychological and physical conditions more than we thought."

This statement indicated that participant (35) referred to scientific work on past diseases such as SARS and their influences on society and humanity.

Limited views: The results also indicated that 4% of participants provided limited views on the combined aspects of science. For example, participant (11) stated:

> "Predictability and systematic exploration can be explained in the battle against COVID-19. Predictability can help us for uncertain situations like this virus … Scientific knowledge makes us question our environment and this improves our curiosity. So, …, we want to learn much more thing. Moreover, if we want to learn much more thing, we must communicate with other people, so this effect our communication skills positively. Therefore, scientific knowledge is needful for humanity."

This statement addressed the participant's views on the value of science, it emphasized the limited views on both empirical and sociocultural embeddedness. In another statement, participant (14) addressed science as universal even though she discussed the social and cultural influences in science. She presented limited views, as below:

> "We try to understand our life from experiments and observations. These experiments are the science. Also, there is a NOS. NOS aims to explain natural incidents. It is part of social and cultural traditions. That's why science is universal for all people. COVID-19 started in China, but it spread all over the world. NOS is related to COVID-19 and interdependent to science. All scientists in the world try to prevent and destroy the virus. They look for some vaccine because of the science. They make some research and experiments. They make experiments about spreading the virus how by scientific methods."

Views of science literacy

The emerging data also provided pre-service mathematics teachers' views on science literacy. The results were variable and focused on linguistic, cognitive, sociocultural, and developmental dimensions of science literacy (Kucer, 2009), as shown on **Figure 3**.

23% of the participants indicated views in the cognitive dimension. 46% of the participants indicated only developmental views; 30% participants' views focused on sociocultural dimension whereas 2% were in the linguistic dimension. For example, participant (10) stated:

> "Science is present in every aspect of our life. We cannot understand neither mathematics nor technology without understanding the scientific language. We cannot solve any problems; we cannot produce new technological lates, we cannot create computer programs. In short, if the language of science was not learned, the world could not be as advanced as it is today. In science, someone who knows the acceleration and mass, that is, who knows the language of science and has done scientific experiments, can easily understand the formula F=m×a in mathematics."

This statement emphasized science literacy as a language to use while using technology and engaging in scientific practices such as conducting experiments.

Most pre-service mathematics teachers focused on cognitive dimension of science literacy. They focused on understanding the fundamental concepts. For example, participant (44) stated:

> "Scientific literacy is important because without this, to understand science would be hard and scientific literacy can better deal with its problems and address some natural problems and then these can be solved more easily."

In this quotation, participant focused on understanding the science content to address the solutions of problems.

Another participant focused on the developmental aspect of science literacy and referred to development of scientific work as dependent on technology, engineering, mathematics, and science to solve the problems. Participant (24) stated:

> "Science addresses issues that have not been resolved in the universe and aims to explain to people the causes and consequences of natural events. Technology, engineering, mathematic, and history are tools that help in the development of scientific literacy. To understand scientific literacy, we have not to look at problems from one perspective so we should search for works that were done previous year."

30% of the participants presented science literacy from sociocultural aspect. Participant (47) referred to influence of mass media in society during the outbreak of a disease. The participant stated:

> "Scientific and technological advances affect every area of our life closely. However, negative behaviors are observed during the transfer of scientific information. To fool the masses, more false information is served to the media. The effect of news content prepared without scientific content is worrying in the social segments whose scientific literacy rate is quite low. So, we must be as conscious as possible, and we must inform society."

Most participants (at least 30% for each) addressed the cognitive, developmental, and sociocultural aspects of science literacy and less of them (2%) addressed the necessity of knowledge of scientific language to deal with the scientific problems in society.

DISCUSSION

The major conclusions from this study address the notion of how pre-service mathematics teachers' definition of science is related to their views of science and science literacy. What are the significance and implications of knowing about pre-service mathematics teachers' views of NOS in the context of COVID-19?

Participants' approach to science and development of scientific knowledge may be related to their perceptions, decisions, what they teach, how they teach, and their approach to teaching and learning in general as well as in specific domains such as mathematics (Fives & Buehl, 2017; Pajares, 1992; Van Driel et al., 2007). Participants' views of NOS in the context of COVID-19 referred to their views of science in relation to their definition of science, and science literacy (**Table 4**).

Table 4. Summary of participants' view of nature of science

Views of science	%	Definition of science	%	Science literacy	%
Empirical	38	Product	28	Cognitive	8
		Process	6	Developmental	20
		Human endeavor	4	Linguistic	2
				Sociocultural	8
Sociocultural	38	Product	24	Cognitive	8
		Process	10	Developmental	14
		Human endeavor	4	Sociocultural	16
Tentativeness	14	Product	10	Cognitive	6
		Process	4	Developmental	6
				Sociocultural	2
Subjectivity	6	Product	2	Cognitive	2
		Process	4	Developmental	4
Limited	4	Product	2	Sociocultural	4
		Process	2		

The results were aligned with the previous research such as Liu and Tsai (2008) and Wong et al. (2009). Most of the pre-service mathematics teachers focused on the empirical (38%) and sociocultural (38%) aspects of science. Regarding the empirical focus, even though pre-service mathematics teachers provided desirable knowledge of science, most of them defined science as a product (28%) in the form of systematic knowledge, disciplinary knowledge, facts or gaining new findings. Their beliefs about science literacy were mostly in developmental level (20%), so they discussed science literacy in terms of understanding the science concepts and applying it in specific situations and to the problems related to society. Only one student (2%) focused on the role of language literacy in the use of experimentation and development of scientific knowledge. These results showed that pre-service mathematics teachers approached science as a static, durable knowledge developed through experimentation to produce new knowledge, inventions or technology. These findings were consistent with Abell and Smith (2001). Their views on empirical focus were also closely related to views on tentativeness aspect that participants defined science as either systematic knowledge or theories-laws-and-models; they emphasized the development of knowledge as a durable product. These participants believed that experimentation and modeling led to find new evidence to understand the science content, construct new explanations, and make developments.

Participants (38%) also indicated desirable views on sociocultural-embeddedness of science. They defined science as a product in the form of systematic knowledge, but they also described science as a process in the form of an explanation of natural phenomenon. These teachers focused on the development of scientific understanding through constructing logical and consistent explanations. Additionally, their beliefs about science literacy focused on mainly sociocultural and developmental dimensions. These teachers discussed social, cultural, economic, and political factors in relation to understanding and application of science and trust in science to provide new findings and improve society (Borgerding & Mulvey, 2022). Leung et al. (2016) found that non-science college students emphasized the cognitive dimension of scientific literacy to understand how science works. The current study found that pre-service mathematics teachers tended to refer to empirical and sociocultural aspects of science in relation to mostly developmental and sociocultural dimensions of science literacy.

Participants also emphasized the role of subjectivity in the development of science knowledge. Only 4% of the participants' views of subjectivity presented the interconnection between process of science and developmental dimension of science literacy. These teachers discussed that different perspectives and methodologies of scientists might lead to differences in results for the same scientific problems. These participants mostly defined science as a process of explanation of natural phenomena from a personal perspective to conduct experiments and produce new results.

Pre-service mathematics teachers (4%) provided limited views on scientific knowledge. They defined science with mixed views as a product and process- both systematic knowledge and prediction, which addressed their beliefs about science literacy on sociocultural dimension. Their mixed views on the definition of science made them believe science as universal.

These results highlight the benefit of explicitly integrating NOS in relation to societal issues in an introductory science and mathematics education course. In this study, pre-service mathematics teachers were given opportunities to provide insights on their views of NOS in a classroom setting. The findings of this study indicated that pre-service mathematics teachers mainly described empirical and tentativeness views as a product accumulated in the form of systematic and durable knowledge necessary to understand the science content and produce new inventions (cognitive and developmental views of science literacy). These results indicated how pre-service mathematics teachers approached to science as an accumulated knowledge driven through systematic experiments; their understanding of how they understood scientists' work and the development new technologies reflected limited views on the definition of science. This study also found that pre-service mathematics teachers could provide desirable views on empirical, sociocultural, tentativeness, subjectivity aspects of science. Similarly, Akgun and Kaya (2020) found that non-science college students had sophisticated views on NOS. However, the current study emphasized that desirable or informed views on aspects of science were related to the participants' views of science literacy in mainly developmental, and sociocultural dimensions, and were misaligned with their definition of science as a product or accumulated knowledge.

Pre-service mathematics teachers' views of NOS may represent their beliefs about teaching and learning in general as well as in specific domains such as teaching and learning mathematics or physics (Abell & Smith, 1994; Tsai, 2008). Most participants were able to understand the role of science as an empirical and sociocultural activity. However, they were not able to question science as a process of knowing to make-sense of the physical world through exploration even though their views on subjectivity aspect represented science as a process. As a next step, we need to understand how pre-service mathematics teachers' beliefs about science is related to their beliefs about teaching and learning in general as well as in mathematics. What counts as constructivist mathematics teaching and how does it relate to teachers' beliefs about science and mathematics? Teacher educators should focus on how teachers' beliefs in general, such as beliefs about teaching and learning, are related to their specific beliefs about NOS and mathematics or other disciplines as well as their classroom practices. To develop advanced science literacy, teacher educators should help pre-service teachers to experience science in different ways while solving science and mathematics related societal problems such as COVID-19 epidemic. Teacher educators should help pre-service mathematics teachers understand how teaching and learning happen in the view of science to develop meaningful understanding of content as well as to promote scientific literacy for all.

Limitations and Implications

This study was conducted in an iterative process to understand what views of NOS pre-service mathematics teachers constructed in the context of an epidemic. The participants were fifty college students selected for this study; qualitative methods and descriptive statistics were utilized to analyze and present the data. The results were applicable to this specific course participants. The results should be carefully considered to generalize since there were six males and 44 females in this study. The large sample of participants should be chosen to compare how teachers' views of NOS differ by gender, age, and teaching experience variables. Additionally, mostly qualitative methods were used to understand the views of science in relation to definition of science and scientific literacy. Studies with mixed or quantitative methodologies should be conducted with large sample size to generalize the results for pre-service mathematics teachers or teachers in other disciplines. Furthermore, the course was interested in views of NOS that pre-service mathematics teachers held by the end of the study, and the study was not interested in the changes in their views. Future research should explore whether pre-service mathematics teachers retain their views after the course, whether post-course assessments indicate durability of their views or not. The course also addressed NOS in an explicit manner through the context of COVID-19. Future research should investigate how the use of different contexts can promote students, teachers, and adults' understandings of NOS. Lastly, teachers' informed, or partially informed (desirable) views may or may not be related to their use of constructivist teaching strategies. Future research should also examine pre-service mathematics teachers' teaching practices in reference to their views of NOS.

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