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THE VIEWPOINTS OF PRE-SERVICE SCIENCE TEACHERS ON THE ESSENTIAL NATURE OF SCIENCE CONCEPTS IN THE SAUDI CONTEXT: A TRIANGULATION APPROACH

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Abstract. *This research examines viewpoints held by pre-service science teachers on key concepts of the Nature of Science (NoS) in the Saudi context. Much research in this context emphasises quantitative methods, so this research utilises methodological triangulation to validate the data. Quantitative data was first obtained from 35 pre-service teachers using a method based on the Myths of Science Questionnaire (MOSQ). A qualitative approach was then applied using an open-ended questionnaire and semi-structured interviews of ten pre-service teachers, adopted from the Views of Nature of Science questionnaire form C (VNOS-C). The pre-service teachers' perspectives on the NoS were found to be lacking, especially regarding scientific knowledge, scientific methods, and the work of scientists. Furthermore, several respondents failed to consider science as a social enterprise. Suggestions and recommendations are provided to address such misinterpretations and poor scientific understandings, which are likely due to a lack of science philosophy content in educational programmes for teachers.*

Keywords: *epistemology of science, Myths of Science Questionnaire (MOSQ), Nature of Science (NoS), pre-service science teacher, science philosophy, Views of Nature of Science form C (VNOS-C).*

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Introduction

Human beings live not only in nature but also interact on a very regular and continuous basis with nature when examining and exploring different phenomena with the aim of presenting potential explanations and rationales. Importantly, creativity and imagination are recognised as tools in this regard. Accordingly, science development continues to need to be used by students and teachers if the nature of science (NoS) is to be well understood. Science plays a pivotal role in both current and future society, as it has done in the past; thus, the scientific literacy of all citizens requires continual development (Sangsa-ard & Thathong, 2014). Understanding the NoS is a fundamental and essential aspect of scientific literacy (Lederman, 1992; Bybee, 1997).

McDonald & Abd-El-Khalick (2017) suggest that one of the key objectives of a number of national science education reform documents on a worldwide scale – including the American Association for the Advancement of Science (AAAS, 1993), the Australian Curriculum and Reporting Authority (ACARA, 2015), the National Research Council (NRC, 2012), and the Next Generation Science Standards (NGSS, 2013) – is to develop the perspectives and views of students regarding the NoS. Thus, NoS teaching and learning is a critical goal of science teachers.

Studies associated with the NoS, as noted in the in-depth review by Lederman (1992), may be broken down into four different, albeit related, lines of inquiry: (1) evaluation of students' viewpoints regarding the NoS; (2) development, application, and evaluation of curricula aimed at enhancing students' conception of the NoS; (3) evaluation of teachers' conception of the NoS, and efforts directed towards enhancing their conception; and (4) establishment of the link between teachers' conceptions and classroom practices, and students' conceptions of the NoS.

As mentioned above, significant reform efforts have been made in science education, including a great deal of discussion and debate on the value of improving students' conceptions of the NoS. Science teachers are pivotal in directing the development of NoS understanding among students. This was highlighted by Lederman (1992), who suggests that teachers should ensure that their students possess an in-depth and comprehensive understanding of what has been taught. Thus, having teachers demonstrate a sound and detailed understanding of the NoS should be one of the most critical and basic criteria towards achieving a successful degree of NoS understanding among students (Abd-El-Khalick & Lederman, 2000; Buaraphan & Sung-ong, 2009).

Science teachers have long considered it to be a pressing concern to ensure that conceptions of NoS are developed among pre-service teachers (Abd-El-Khalick, Bell & Lederman, 1998; Palmquist & Finley, 1997). However, studies assessing teachers' perspectives on science have shown that teachers commonly hold inadequate and somewhat misinformed views (Lederman, 1992). According to some works, most teachers consider that scientists adopt pre-established, detailed scientific methods; as a result, teachers view scientific frameworks as being imitations of nature rather than human constructions. Moreover, teachers commonly disregard the role of creativity and imagination in science. It has also been suggested that teachers tend to adopt a somewhat simplistic and hierarchical link between hypotheses, laws, and theories (Buaraphan & Sung-ong, 2009).

The Nature of Science

The nature, or philosophical background, of science (i.e., the NoS) refers to the epistemology of science – that is, to the beliefs and values that are seen as aligning with scientific knowledge or its development, or to science as a way of knowing (Lederman, 1992). Abd-El-Khalick and Lederman (2000) state that the key objective of science is to gain knowledge and understanding of the physical world; thus, pure science is not linked to applications, outcomes, or other uses (with the exception of new knowledge creation). Like scientific knowledge, perspectives on the NoS are dynamic and tentative, and have changed significantly with science development. An important argument posits that with the development and growth of science, and our expanding everyday understanding of our surroundings, perspectives on the NoS will similarly evolve (Suchting, 1995).

Thus, conceptions of the NoS have changed considerably over time, in line with developments in various science disciplines and redirections in the focus of the history, sociology, and philosophy of science. In fact, the 20th century can be broken down into two distinct phases, each with a different focus on the philosophy and sociology of science. The shift from one phase to the next was triggered by the publication of Kuhn's (1962) structure of scientific revolutions. Kuhn's method presented a key change in direction: from an emphasis on justification to an emphasis on discovery. A great deal of criticism was directed towards Kuhn's paradigmatic approach (Popper, 1970), which was seen to incorporate irrationalities and relativism into scientific knowledge development. Nevertheless, a key quality of the post-Kuhnian philosophy of science is its fixation with integrating various accounts of science with actual scientific practice. Thus, accounts of science are validated through descriptive explanations and interpretations of laboratory studies and through the sociological examination of scientific discourses (Abd-El-Khalick & Lederman, 2000).

Scharmann & Smith (2001) have suggested that it is probably impossible to attain consensus on the NoS. In fact, it has been stated by National Science Teacher Association (NSTA) (1998) that historians, philosophers, science educators, and scientists have thus far been unable to achieve consensus regarding a definition of the NoS. However, a general, sound overview of the NoS has been presented by McComas, Almazroa, & Clough (1998). These scholars present the NoS as a fertile, hybrid arena that can bring together various elements of science and social studies. The work of McComas et al. encompasses the history, philosophy, and sociology of science, and includes research from cognitive science (including psychology). It provides an in-depth and detailed account of what science may be seen to encompass, as well as how it functions, how scientists operate, and how scientific efforts are both directed and received by society.

Despite the overall lack of consensus, a general level of understanding has been established regarding the NoS. This level is considered to be both accessible and relevant to K–12 (kindergarten to Grade 12) students (Abd-El-Khalick & Lederman, 2000). Furthermore, some degree of agreement has been established regarding the various aspects of the NoS that must be included in science curricula (McComas & Olson, 1998). For example, McComas & Olson (1998) examined eight international science standard documents and identified an overall level of agreement on the NoS.

Aspects of the NoS include the following:

(1) Scientific knowledge is speculative and therefore unconfirmed; there is no single scientific method, although there are scientific approaches with similar traits.
(2) Imaginative play and creativity are fundamental in scientific knowledge development.
(3) Theories and laws adopt different scientific roles.

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(4) There is a link between inferences and observations.
(5) Although science is focused on ensuring an objective stance, there is an aspect of subjectivity in scientific knowledge development.
(6) Scientific ideas are influenced by their historical and social environment.

Four aspects of the NoS build the conceptual framework, and are discussed below: scientific knowledge, scientific method, scientists' work, and scientific enterprise.

Scientific Knowledge

Hypotheses, theories, and laws are essential parts of the NoS. Science teachers have been found to believe that when a hypothesis is proven correct, it becomes a theory. After a theory has been proven true many times – by sufficient evidence or by different people – and has been accepted for a long time, they consider that it becomes a law (Buaraphan & Sung-ong, 2009). However, on examination, this perception is inaccurate. As an example, gravity is recognised as pivotal in the Theory of Relativity presented by Einstein. Despite the fact that the basic law of gravity is solid in the theory, nonetheless, the theory itself widens the concept of gravity in such a way so as to encompass a number of different complicated situations, comprising both time and space. It is important to highlight that, although both laws and theories are accompanied with clear empirical data and evidence, nonetheless, both are recognised as presenting different forms of knowledge, with neither one recognised as being the same as the other (Sarkar & Gomes, 2010). Thus, most science teachers perceive scientific theories as a lesser type of knowledge than laws. However, scientific theories are much more complex and dynamic than laws, as they present inferred explanations and often include laws (Abd-El-Khalick, Bell, & Lederman, 1998).

In addition, science is generally viewed as being tentative, as it changes or develops as new information becomes available. However, science teachers have been found to believe that scientific knowledge is a collection of facts or body of knowledge that explains the world; therefore, they regard scientific knowledge as being static (Buaraphan & Sung-ong, 2009). In fact, even though scientific knowledge is durable, it is never absolute or certain (Sarkar & Gomes, 2010). When new evidence is found that contradicts existing knowledge – whether due to technological advancement or the reinterpretation of old evidence in light of a new theory – existing knowledge can be altered (Lederman, 2004). Most pre-service science teachers strongly believed that scientific knowledge is cumulative (Haidar, 1999). Thus, they believed that the advancement of science depends heavily on the accumulation of facts rather than on changes in theory (Haidar, 1999). However, Kuhn (1962) explained scientific progress as being based on competing models or paradigms, instead of on the accumulation of objective knowledge. Kuhn believed that revolutions are disputes that cannot be determined by rational, logical argument.

One popular uninformed conception of the NoS that is held by most science teachers is the idea that scientific models are copies of reality (Haidar, 1999). In their view, scientific models are copies of reality rather than human inventions, either because scientists say that they are true or because a considerable amount of scientific observation and/or research has shown them to be true (Haidar, 1999; Buaraphan & Sung-ong, 2009). In fact, although scientific models are based on empirical scientific knowledge, they involve scientists' imagination and creativity (Lederman, 2004). For example, the concepts of atoms, black holes, force fields, and species are not faithful copies of reality; rather, they are functional theoretical models that creatively integrate the NoS with its inferential nature (Sarkar & Gomes, 2010).

Scientific Method

The scientific method is commonly perceived by science teachers as being a universal step-wise method (Dogan & Abd-El-Khalick, 2008; Haidar, 1999). Hence, they consider that only a single 'scientific method' can guarantee the development of scientific knowledge. This perception can be attributed to the science curriculum, which presents the scientific method as a sequence of steps that all students must follow exactly in order to obtain certain results (Haidar, 1999). In the study of Buaraphan& Sung-ong (2009), it is emphasised that teachers in their pre-service stage view experimentation as a fundamental approach to verifying scientific knowledge. Furthermore, pre-service teachers are also highlighted as communicating a very universal perception, as noted in the work of Thye & Kwen (2003), with teachers maintaining scientific knowledge as being equal to experimental knowledge.

Scientists' Work

Many pre-service science teachers strongly believed the NoS is subjective and objective, theory-laden and theory-free, or value-laden and value-free (Buaraphan & Sung-ong, 2009). However, Popper (2002) argues that scientists move from theory to observation, and not the other way round. Popper also argues that observation is constantly enacted in the light of some interest or point of view. Thus, it is absurd to suppose that scientists begin with pure observation and no prior theory, and that science could develop from such observation into theory. Golshani (2005) argues that interpretation, metaphysical presupposition, and background may intrude when scientists introduce their concepts. The difference between various scientists manifests itself in the selection of theories and in the way of interpreting empirical data. This is particularly true when dealing with general explanatory theories (Golshani, 2000). Theistic scientists, philosophers, and researchers look at the facts and try to assimilate them in terms of their theistic contexts, whereas atheists interpret the facts in terms of their atheistic context (Golshani 2000, 2005). However, pre-service teachers were found to argue that if scientists used creativity and imagination, then they would not obtain accurate results (Buaraphan & Sung-ong, 2009). Pre-service teachers did not seem to think that creativity and imagination were required as steps in scientific investigation (Thye & Kwen, 2003). However, as noted earlier, imagination and creativity are important in areas such as scientific models (Abd-El-Khalick, Waters, & Lee, 2008 ; Lederman, 2004).

Scientific Enterprise

Social and cultural influences on scientific enterprise are explicitly recognised by science teachers (Akerson, Morrison, & McDuffie, 2006). According to Haider (2002), 48% of Arabic university professors agreed that their religious views influenced their scientific research. As mentioned earlier, scientists in the West also construct theories that are appropriate for their secular subculture. It is held by science teachers that the link and interaction demonstrated between technology and science, such as through knowledge, presents a foundational knowledge base for technology, with technology affecting and influencing the development and progression made in science (Rubba & Harkness, 1993). However, misconceptions often occur among teachers in this regard, such as the concept that 'technology is applied science' (Tairab, 2001).

The Importance of Teachers' Understanding of the NoS

Learning and understanding the NoS is recognised as fundamental and as one of the key aspects of science structure (Schwab, 1978). There are two main aspects in any knowledge discipline. The first is substantive knowledge, which is demonstrated through the set of concepts, laws, and theories within the accepted paradigm (Kuhn, 1962). The second is syntactic knowledge, which is demonstrated by evidence determined by discipline professionals, and by the way in which knowledge is provided and accepted. Within the natural sciences, Alshamrani (2012) emphasises that substantive knowledge refers to scientific knowledge, while syntactic knowledge refers to the NoS. It is noteworthy that concepts, theories, and scientific laws are insufficient alone; it is necessary to learn how such scientific knowledge can be obtained and accepted.

Thus, the wide-ranging and detailed history of the NoS is a critical aspect of science curricula (Lederman, 1992). This is mainly because having an understanding of the NoS assists individuals in garnering scientific knowledge on their own; they can then apply this knowledge to gain a well-rounded view of their own environment. Similarly, an understanding of NoS may be pivotal in allowing people to identify and acknowledge the value of science and its restrictions and effects (Lederman, 1992). In essence, understanding the NoS helps students to become capable and well-informed consumers of scientific knowledge; this subsequently enables them to make informed and well-considered choices. There is a common association between citizenship goals and decision-making, and the science curriculum, which centres on the links between science, technology, and society (STS). Highlighting and identifying the value of the investigative nature of science, and acknowledging science as an approach to developing knowledge, implies that the curriculum affects the overall understanding of students in relation to NoS.

Driver, Leach, Millar, & Scott (1996) presented five reasons supporting NoS inclusion as a foundation of science teaching. An understanding of the NoS improves the following aspects in science teachers and students: (1) science content learning; (2) understanding of science; (3) interest in science; (4) understanding of science-related issues,

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and corresponding decision-making; and (5) deliverance of science instruction. Clearly, in order for teaching and learning to be a success, it is pivotal to ensure that teachers have a good understanding of the NoS.

Similarly, Clough & Olson (2012) consider that effective NoS instruction can help students to understand science content. These scholars argue that the NoS assists learners in understanding and moving forward from the statements and hypotheses that underlie scientific knowledge. They also consider that an understanding of the NoS piques learners' interest in science; as a result, enthusiasm and passion surround the learning of science content. Clough and Olson note that when teachers explain how science concepts are constructed and reconstructed as part of the NoS, students can better understand that some of their own ideas are not dissimilar from those of 'real' scientists.

Focusing on students' understanding of the NoS will clearly bring forward a number of epistemological considerations, which can be seen as a way of assisting learners to develop science competence (Matthews, 1998). Such justifications are valuable, since few science learners go on to become scientists. Therefore, it is more pressing than ever to focus on the NoS and its understanding, and on how teachers can influence students in this regard (Lederman, 1992). Furthermore, such a focus could influence the way in which science is taught in the classroom.

Teachers' Views on the NoS

The views of pre-service science teachers on the NoS were examined by Palmquist & Finley (1997). These scholars focused on explaining the changes that occur in such views throughout the course of teacher education. A total of 15 student teachers from a post-baccalaureate secondary science teaching programme were involved in the research. The subjects' views on subjects pertaining to science were collected through an investigator-devised survey and a follow-up interview. The survey was carried out before the science education stages of the programme, and the interview was conducted at the end. Prior to the teaching programme, the subjects were seen to have adopted a modern-day – that is, post-positivist – view on scientific knowledge, scientific theory, and the role adopted by scientists. They also had a more conventional – that is, positivist or empiricist – perception of the scientific method. At first, relatively equal numbers of student teachers fell into the categories of 'modern-day', 'mixed', and 'conventional' perspectives on science. However, after the programme, subjects with 'modern-day' views were double those with 'mixed' views, which had declined by more than half. The subjects with a 'modern-day' view of science had increased from two to seven. Interestingly, the programme in question contained no direct instruction on the NoS. Thus, this research indicates that it is feasible to positively impact the views of pre-service teachers on the NoS by focusing on teaching contemporary teaching methods, including cooperative learning and conceptual change.

Abd-El-Khalick et al. (1998) investigated the factors that affected how the views of 14 pre-service secondary science teachers on the NoS were translated into their instructional planning and classroom practice. To evaluate their overall views of the NoS, the subjects were asked to complete open-ended questionnaires. The subjects then underwent individual interviews to validate their responses to the questionnaire and to establish any limitations or factors that might affect the translation of their NoS-related views into their science teaching. The subjects were seen to have a sound understanding of various NoS elements, such as the difference between inference and observation, the tentative and empirical nature of science, and the roles of creativity and subjectivity in science. A number of the subjects stated that they had already been involved in NoS teaching through science-related activities. Nonetheless, the researchers recognised that clear NoS-based references were lacking in the planning and instruction of the pre-service teachers. The subjects communicated a number of factors that could be responsible for this lack of emphasis. These factors included: considering the NoS to be less valuable than other instructional outcomes, having a lack of comfort with their own perceptions of the NoS, having inadequate experience and resources in NoS teaching, having a lack of planning time, and having a fixation on classroom management.

Murcia & Schibeci (1999) investigated a sample of 73 teachers regarding their views on science using a questionnaire on health and alcohol consumption. One of the questions asked whether the respondent considered that alcohol consumption of more than once a week could lead to serious illness or death; however, the true aim of the question was to establish whether the respondent believed that a scientific fact could be identified from a single study. Importantly, only one third (29%) of the subjects suggested the need for further work to ensure the proof of the statement. The teachers were subsequently asked a variety of true or false questions on other elements of science. One question specifically targeted the way in which scientific theory could be defined. The answers showed that fewer than half (45%) of the subjects were able to indicate that theories have explanatory power that extends beyond the direct observations that were applied to the generation of the theory.

Craven, Hand, & Prain (2002) sought to investigate the views of elementary pre-service teachers on the NoS. A 15 week course was designed to teach student teachers about the NoS and help them progress from a limited perception of the NoS to a more in-depth, comprehensive view. A number of key changes were established regarding the language that was used by the pre-service teachers when explaining the NoS. Craven et al. concluded that when learners are able to communicate their explicit and tacit knowledge of science, a richer and more comprehensive view of science may result.

Buaraphan & Sung-ong (2009) applied the Myths of Science Questionnaire (MOSQ) to a sample of 113 Thai pre-service science teachers with the aim of investigating their perspectives on the NoS. The research focused on perspectives regarding the scientific method and scientific knowledge, the work of scientists, and scientific enterprise. The findings showed that nine of the 14 items on the MOSQ demonstrated consistent response patterns, of which five were informed and four were uninformed. The most significant percentage of uninformed responses related to science as cumulative knowledge; that of informed responses related to the tentativeness of science; and that of uncertain responses related to the overall capacity of science to provide answers to all questions.

Örnek (2014) examined the perceptions of science teachers in Turkey towards the NoS. The methodology applied in the work comprised the Views of Nature of Science questionnaire form C (VNOS-C; Abd-El-Khalick et al., 1998), the Myths of Science survey (McComas, 1998), interviews to monitor and identify changes in the NoS perspectives held by the pre-service science teachers upon the conclusion of the course, and video recordings of the NoS workshop that was held during the second semester. The purpose was to adopt an explicit-reflective instructional practice that improved pre-service science teachers' overall views on the NoS. Importantly, it was found that teachers' views on NoS-relevant aspects were significantly improved and expanded. It is notable, however, that less significant gains were seen regarding the cultural, social, and subjective aspects of the NoS. These findings provide valuable information on the effects of an explicit-reflective NoS instruction.

The Saudi Context

One of the most valuable roles of scientific education relates to the rehabilitation for life among students; the method used to achieve this rehabilitation is a focus on scientific culture. In line with this view, Bybee (1997) posits that one of the most apparent and commonplace patterns in present and future restructuring of scientific education is and will be the aim to establish scientific culture. In fact, scientific culture has become one of the most pivotal trends in science curricula in most countries across the globe, including the Kingdom of Saudi Arabia (KSA) (Alshamrani, 2012). Many science curricula from around the world are known to focus on helping learners gain sound insight into the NoS, with science being recognised as a means of obtaining knowledge. The KSA has devised its science curricula to attain a number of different objectives. These include: the acquisition of scientific knowledge, scientific thinking, problem-solving, and scientific trends; and the attainment of an overall understanding of the NoS, the environment, society, and technology (Alshamrani, 2012; Abu-Athera, 2013). Therefore, it is fundamental to ensure that Saudi universities provide an education that prepares science teachers to achieve these goals.

Alshahrani (1996, cited by Abu-Athera, 2013) examined the overall degree of understanding that pre-service science teachers have of the NoS, within the specific context of the College of Education and College of Teachers at Abha in the south of Saudi Arabia**.** That work also examined the results that were obtained after teaching an NoS-based understanding. In addition, Alshahrani considered the statistical differences between pre-service science teachers' understanding of the NoS and their views on the NoS. Lastly, that work examined the link between degree of NoS understanding and attitude towards the NoS, as held by student teachers. The research data were gathered using the Science Attitude Questionnaire, along with a test that aimed to gain insight into the NoS, as devised by Al-Shargi (1993, cited by Abu-Athera, 2013). Examination of the data led to a number of conclusions, as follows:

Understanding of the NoS was low;

- Science was viewed positively;
- Teaching a science method course with a focus on NoS understanding had a positive effect;
- A greater understanding of the NoS was achieved by pre-service science teachers at the College of Education than by those at the College of Teachers;

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- No changes in the attitudes towards science regarding NoS understanding were identified; and
- No significant statistical differences were identified between attitude mean scores towards science across both the college populations.

Abu-Athera (2013**)** also investigated the views of pre-service science teachers on the NoS. This research utilised a sample of 40 pre-service science teachers at the University of Taif in the west of Saudi Arabia – notably, those who were at the diploma level in the Faculty of Education. The MOSQ was used in this research, and the findings were as follows. (1) Pre-service science teachers hold the view that scientific theories are not as consistent as laws. Scientific knowledge is recognised as continuously evolving, and 34% of the respondents consider that scientific models represent reality. (2) The respondents believe that the scientific method and science itself cannot provide answers to all questions, and that knowledge is not derived from the completion of experiments. (3) The respondents recognise that scientists utilise imagination and creativity when developing scientific knowledge. (4) The respondents consider that scientific enterprise is not an individual entity, and that the development of scientific knowledge affects culture, politics, and society.

Furthermore, the findings suggested that there is a lack of understanding and clarity pertaining to the NoS among pre-service science teachers, as follows: (1) Some of the respondents considered that mere assumptions are built upon in order to develop theories. They viewed scientific laws as stemming from scientific theories and their development. They also considered that gathering evidence positions scientific knowledge in a more consistent and reliable light. (2) More than one third (38%) of the respondents held the view that reality is reflected in scientific models. (3) Respondents considered that the scientific approach is a strict, step-by-step approach. (4) Respondents lacked understanding of scientific enterprise, and maintained the view that technology and science are one and the same.

As described above, a number of different works have been carried out to establish the views, conceptions, and understanding that pre-service teachers have of the NoS. This research shows that student teachers from different age groups, and even teachers, hold misleading views of the NoS, irrespective of the tools applied when conducting investigations (Lederman, 1992). Furthermore, various studies have emphasised that misconceptions on the NoS are frequent and commonplace among teachers (Lederman, 2007).

Nonetheless, research is lacking on teachers in the Saudi context; therefore, the present work seeks to fill this gap. As noted by Saif (2016), very few works have been carried out in the KSA regarding different NoS elements.

Problem of Research

One of the main aims incorporated within the new science curriculum in Saudi Arabia is the development of the viewpoints of learners in relation to NoS (Alshamrani, 2012).Irrespectively, however, significant professional development afforded to teaching staff remains lacking when it comes to the demands inherent in the new curriculum. Accordingly, this research presents the view that, if teachers are lacking in sound and reasonable levels of insight in regards NoS, they will be unable to communicate NoS views to students—even in cases when NoS views are well considered and discussed in the curriculum and textbooks. Conventional scientific professional science education, in the modern-day world, requires supplementation with more novel, modern general science. As a result, pre-service science teachers' views in regards NoS are acknowledged as being fundamental due to their capacity to affect the implementation of science curricula, with adoption carried out in such a way that is complimentary with their own view of NoS.

The following questions guided the research:

1. What are the views of pre-service science teachers on scientific knowledge, specifically within the context of the KSA?
2. What are the views of pre-service science teachers on the scientific method, specifically within the context of the KSA?
3. What are the views of pre-service science teachers on scientists' work, specifically within the context of the KSA?
4. What are the views of pre-service science teachers on scientific enterprise, specifically within the context of the KSA?

Research Focus

To achieve effective science teaching, teachers' understanding of the NoS should be sound and comprehensive (McComas et al., 1998). Therefore, the present research explores the conceptions held by pre-service science teachers on the NoS, within the Saudi context. The findings of this research contribute to the somewhat limited literature in this domain. In addition, this research may support science educators in their plans to promote and encourage a thorough understanding of NoS among both pre-service teachers and acting teachers.

Methodology of Research

General Background of Research

The research data were obtained through methodological triangulation, utilising a sample of 35 pre-service science teachers at a university in a northern province of Saudi Arabia. The research focused on establishing the viewpoints held by pre-service science teachers on key concepts of the NoS. Quantitative data were collected in 2018 using a method based on the MOSQ. A qualitative approach was then applied through an open-ended questionnaire and semi-structured interview adopted from the VNOS-C.

Research Participants

Convenience sampling was applied to choose the sample of pre-service science teachers for this research. The administrative staff at the College of Education at Jouf University in northern Saudi Arabia was asked to devise a list of emails for all pre-service science teachers (*N* = 35). An e-mail was then distributed to all pre-service science teachers, detailing the research purpose. Two weeks later, responses to the e-mail were reviewed. A total of ten teachers showed interest in being involved in the research and agreed to participate in a semi-structured interview.

First, the MOSQ was administered by the researchers at Jouf University to the sample of 35 pre-service science teachers. After 10 days, the VNOS-C was administered to the same sample of 35 teachers. Two weeks later, semi-structured interviews were carried out with the ten pre-service science teachers who had agreed to be involved. Although the number of participants participating in the semi-structured interview was very small, the possibility of volunteer bias was mitigated somewhat by the researchers making no attempts to generalise the results to apply to a wider population. As per the tenets of qualitative research, insights from these data were confined to this sample (McGregor, 2018; Polit & Beck 2008).

Triangulation was implemented in this research by using multiple methods to cross-reference the collected data, thus enriching its overall validity. Although every method has its own strengths and weaknesses, applying different strategies to investigate the same phenomenon permits a more in-depth, comprehensive, and reliable insight to be achieved. Hence, interviews were performed with pre-service science teachers to ensure that real and accurate points of view were ascertained and thus to establish the overall validity of the answers received. In future, educational researchers focusing on the Saudi context are encouraged to employ more rigorous sampling protocols with larger sample frames. It is worth mentioning that the city from which the pre-service teachers in this research were selected – that is, Al-Jouf City – is a typical city with very similar cultural features to other cities in Saudi Arabia. Therefore, choosing a different region would be unlikely to affect the representativeness of the sample. Furthermore, all pre-service science teachers in Saudi Arabia study in colleges of education that offer the same courses and training. In this case, Al-Jouf City was chosen because the researcher lives and works there, making it easier to conduct the research.

Data Collection

After reviewing and analysing the answers to the research questions, a methodological triangulation approach was adopted, including a quantitative (Likert-type) approach and a qualitative approach (using open-ended questionnaires and interviews). Only two works have been carried out to examine the understanding of science teachers towards the NoS within the same context (Abu-Athera, 2013), and both adopted a quantitative approach. Therefore, this research provides a first attempt at garnering both qualitative and quantitative data within this context. The gathered evidence was cross-checked, as suggested by Scott & Morrison (2007), by collecting differ-

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ent forms of data relating to the same phenomenon. This method is recognised as a means of providing validation and ensuring data accuracy.

Phase One

In the first phase, the MOSQ (McComas, 1998) was applied. This tool comprises 14 items centred on dealing with four different elements of the NoS, namely: scientific knowledge, which spans items 1–4, 8, and 9; the scientific method, which spans items 5–7; scientists' work, which spans items 10–11; and scientific enterprise, which spans items 12–14. The respondent chooses one of three possible answers – agree, uncertain, or disagree – depending on his or her opinion.

The MOSQ was validated by five science educators, with a focus on relevance and clarity. Revisions were then made in line with the professionals' feedback, resulting in a revised version of the MOSQ. A pilot study was then carried out across a sample of 17 pre-service science teachers in order to establish whether or not the questionnaire could be well understood and easily completed.

Phase Two

In the second phase, pre-service science teachers completed the open-ended questionnaire (N = 35) and underwent semi-structured interviews (N = 10). The questionnaire was based on the VNOS-C, as presented in another work. Lederman, Abd-El-Khalick, Bell, & Schwartz (2002) developed an open-ended questionnaire emphasising various NoS-related aspects, including the empirical nature of the NoS, the link between observational inference and theoretical entities in science, the differences between theories and laws, scientific knowledge and its creative and imaginative nature, scientific knowledge's nature of theory, the cultural and social core of scientific knowledge, the scientific method and related myths, and the tentative nature of scientific knowledge. This questionnaire was validated through testing across a number of college students (graduate and undergraduate) and teachers (both in-service and pre-service from elementary and secondary schools) (Lederman et al., 2002). NoS profiles were created of the participants after individual examinations of the interview transcripts and questionnaires. By drawing a comparison between participants' NoS profiles and their responses to the VNOS-C, it was seen that the NoS conceptions held by the participants as revealed through the VNOS-C aligned with the conceptions communicated by the participants throughout the course of the interviews.

The devised questions were translated from English into Arabic, and were then distributed to two assistant professors who had completed Ph.D. degrees in Biology at Glasgow University and in Science Education at York University, respectively. Content validity of the questions that were posed in the semi-structured interviews and open-ended questionnaires was established by more than ten different faculty members from Jouf University, in addition to various science education course supervisors and teachers. Furthermore, opinions on the overall suitability of the questions' content were sought.

As mentioned earlier, in order to establish the overall validity of the data obtained from the pre-service science teachers, various data-collection approaches (triangulation) were applied. A total of ten pre-service teachers were interviewed two weeks after their first responses. A comparison was subsequently drawn between the ten participants' responses to the MOSQ and VNOS-C, and their responses during the interviews; significant agreement was established. The validity of the participants' responses was further established through an analysis that was completed with another researcher: the current researcher examined ten responses from a student, while another researcher in the field of scientific education examined the same responses from the same student. Compatibility between the results of the current researcher and those of the other specialist was 98.5%.

Ethical Issues

To ensure ethical considerations, the pre-service science teachers involved in this research were provided with informed consent forms to read and sign prior to the research being completed. The teachers were informed of the purpose of the research and what tasks would be carried out. They were also advised that they could withdraw from the research at any stage without providing a reason. During the research, the pre-service science teachers' privacy was respected and taken seriously. During data collection, participant confidentiality was ensured by having the participants not disclose their names or personal information, and by only collecting relevant details that would help in answering the research questions. In addition, the pre-service science teachers were assured that the data-collection process would have no influence on their professional position.

All of the collected data were securely protected on a password-protected computer during the research. The participants had the right to be fully briefed about the aims, process, and findings of the research. The resulting feedback, implications for research, and findings gave the participants a sense of the data that had been collected. It also allowed them to confirm that the data portrayed their true views and ideas, and accurately reflected their knowledge and opinions.

Results of Research

The findings ascertained from this research are presented in two parts: the first part describes the data that was gathered through the completion of the MOSQ, and the second part describes the data that was gathered through the completion of the VNOS-C and the semi-structured interviews.

The Views of Pre-Service Science Teachers on the NoS: Data from the MOSQ

Each response's frequency, i.e. agrees, uncertain and disagree, were first counted and then accordingly calculated in order to establish their individual percentages. Interpretations were made, in this regard, detailed as informed, uncertain and uninformed in regards NoS.

The MOSQ: Scientific Knowledge

As shown in Table 1, more than one third (37.8%) of the sample held a traditional view pertaining to hypotheses and theories, as shown by their agreement with Statement 1 – 'Hypotheses are devised only in mind of becoming theories.' Almost one in four (24.3%) of the sample were uncertain regarding Statement 1. These findings could be because pre-service teachers in Saudi consider that when hypotheses are validated, they become theories. Thus, a scientific theory is viewed as the final state in the scientific method-devising process. Moreover, most pre-service science teachers (81.1%) communicated a conventional view by agreeing with Statement 2 – 'Scientific laws are more secure than theories'. This view may relate to the opinion that theories are not as credible as laws, which stems from the fact that theories can be changed, whereas laws are fixed and cannot be changed. This association becomes apparent when considering that more than two thirds (67.6%) of the subjects agreed with Statement 3 – 'Laws can become laws provided there is development in scientific theories'. In other words, 67.6% agree that laws are derived following the development of scientific theory. This data further suggests that pre-service science teachers in the Saudi context consider laws to be mature theories.

Table 1. Scientific knowledge.

Items	Percentages (%)		
	Agree	Uncertain	Disagree
1. Hypotheses are devised only in mind of becoming theories.	37.8	24.3	37.8
2. Scientific laws are more secure than theories.	81.1	8.1	10.8
3. Laws can become laws provided there is development in scientific theories.	67.6	16.2	16.2
4. No changes can be made to scientific knowledge.	2.7	24.3	73.0
8. Evidence-gathering ensures stability in scientific knowledge.	64.9	18.9	16.2
9. Scientific models (such as the atomic model) may be considered a replication of reality.	62.2	0	37.8

A large portion of the sample of teachers (73%) held a traditional view on scientific knowledge being unable to undergo change (Statement 4). This finding indicates that pre-service teachers in the KSA consider science to be static, consistent, and therefore unchanging (Craven et al., 2002). Thus, they perceive science as a body of knowledge or facts that provides explanations of the world and our environment, and that does not require further expansion. Similarly, a large proportion of the sample (64.9%) agreed with the conventional view that gathering evidence en-

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sures a greater degree of stability in scientific knowledge (Statement 8). The members of this group thus appear to have a minor degree of awareness regarding the tentative nature of science and the role of cumulative knowledge.

In addition, almost two thirds (62.2%) of the subjects agreed with Statement 9 – 'Scientific models (such as the atomic model) may be considered a replication of reality'. This finding may be rationalised by considering that the student teachers view scientific models as being created and established in line with the completion of experiments, devising of theories, and finalisation of laws. Thus, these individuals may view the atomic model as an example of empirical concepts.

The MOSQ: Scientific Method

As shown in Table 2, almost half (48.6%) of the sample showed agreed with Statement 5 – 'A strict step-by-step approach is applied in scientific methods'. This finding indicates that these individuals consider the scientific method to be consistent and fixed. Statement 6 – 'All questions can be answered through science and scientific methods' – yielded a relatively wide distribution of answers between Agree, Uncertain, and Disagree; almost half (40.5%) of the sample disagreed with Statement 6, more than a third (37.8%) were uncertain, and one fifth (21.6%) agreed. Nonetheless, the majority (83.8%) of the respondents held a conventional perspective in relation to Statement 7 – 'Experiments are the only means of arriving at scientific knowledge'. Accordingly, the data suggests that the sample under study is aligned with the view that experiments are the key means of arriving at scientific knowledge (McComas, 1998).

Table 2. Scientific method.

Items	Percentages (%)		
	Agree	Uncertain	Disagree
5. A strict step-by-step approach is applied in scientific methods.	48.6	24.3	27.0
6. All questions can be answered through science and scientific methods.	21.6	37.8	40.5
7. Experiments are the only means of arriving at scientific knowledge.	5.4	10.8	83.8

The MOSQ: Scientists' Work

A large proportion of the sample (83.3%) disagreed with Statement 10 – 'When developing scientific knowledge, imagination and creativity are not used by scientists'. Thus, this research sample holds a modern view on the role of creativity and imagination in the work of scientists, and considers scientific creativity to be important. In contrast, however, almost two thirds (64.9%) agreed with Statement 11 – 'Scientists demonstrate open-mindedness without bias'.

Table 3. Scientists' work.

Items	Percentages (%)		
	Agree	Uncertain	Disagree
10. When developing scientific knowledge, imagination and creativity are not used by scientists.	10.8	2.7	86.5
11. Scientists demonstrate open-mindedness without bias.	64.9	21.6	13.5

The MOSQ: Scientific Enterprise

As shown in Table 4, the pre-service teachers making up the research sample adopt both conventional and modern views on the link between science and technology; the same proportion of the sample (40.5%) both agreed and disagreed with this statement. Nonetheless, a large portion (83.8%) disagreed with Statement 13 – 'Scientific enterprise is recognised as only one enterprise'. In addition, the vast majority (91.9%) of the subjects disagreed with

Statement 14 – 'Culture, politics, and society do not influence scientific knowledge development'. This suggests that the pre-service teachers are aware of the influences of cultural and social factors on scientific practice, and that many of the teachers dismiss the idea of science as a social enterprise or as a type of human cultural activity.

Table 4. Scientific enterprise.

Items	Percentages (%)		
	Agree	Uncertain	Disagree
12. Science and technology may be viewed as one and the same.	40.5	18.9	40.5
13. Scientific enterprise is recognised as only one enterprise.	2.7	13.5	83.8
14. Culture, politics, and society do not influence scientific knowledge development.	8.1	0	91.9

The Views of Pre-Service Science Teachers on the NoS: Data from the VNOS-C and Semi- Structured Interviews

This section presents the thoughts of the subjects on the NoS, as obtained from the VNOS-C questionnaire and the subsequent semi-structured interviews. Individual attention is given to the perspectives of the subjects on each of the individual elements of the NoS, as follows: science as tentative and subjective, science as empirically based, science as influenced by human inference, creativity and imagination in science, science as culturally and socially embedded, the identifiable differences between scientific laws and theories, the differentiation to be made between inference and observation, and myths relating to scientific approaches.

The VNOS-C and Semi-Structured Interviews: Science is Tentative and Subjective

Questions 4 and 8 were posed in order to establish the ideas of the pre-service teachers on the percentage of practical knowledge and its overall inconsistency. Question 4 aimed to establish the subjects' perception of a scientific theory and its propensity towards changeability. The findings showed that six of the subjects chose not to answer this question, while three considered theories to be unable to change:

> Theories cannot change. (S 6)

Most of the respondents (*N* = 26) considered that a scientific theory develops without changing; that is, that a scientific theory encompasses an invariable aspect, although the aspect remains open to change, development, and increase:

> There is the chance that theory could change, although the main idea at the core would be the same. (S 20)

Of the subjects who responded to the question on the ability of scientific theory to change and develop, 15 gave examples to support their answers, and six emphasised atomic theory development.

> A theory can change. Take the atomic theory, for example. People think Dalton was at the beginning of this, with Faraday, Thomson, Rutherford, and Bohr providing further developments until the modern atomic theory was finally presented. (S 21)

Three subjects provided examples regarding the scientific approach to a cell; another three provided examples regarding space, and noted how theories on the universe have changed from the centrality of the earth to that of the sun:

> Scientists used to hold the view that the sun rotates around the earth, and it was more common than not to hold that view in those days. But it was then discovered that the sun rotates around its own axis. In other words, it doesn't move. And against what was initially thought, planets, such as our own earth, were then found to rotate around the sun. (S23)

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Two other subjects provided examples on the theory of evolution and how scientists' own perspectives changed regarding the origin of life. Another subject provided an example that went from classical physics and its changes, with an emphasis on the Newton's three laws, through to modern-day physics, with an emphasis on the theory of relativity. It was notable that one subject maintained that a scientific theory is able to change and develop, and another nine subjects suggested that scientific theories evolve as a result of newly discovered evidence, research, and other approaches to scientific study. During one of the interviews, a subject provided the following statement:

> A scientific theory can be seen to grow and develop owing to the fact that scientists in the field implement innovative approaches and consider alternate theories when performing scientific research. (S 22)

Three of the subjects stated that other factors – namely, religious and social factors – encouraged scientific theory development, and two subjects stated that new tools and resources are a key consideration that facilitate the development of scientific theories:

> A theory can be continuously changing owing to theories benefitting from religion fundamentals. Take evolution theory, for example, which has presented the view that man has changed from being a monkey. But then consider evidence detailed in the Islamic faith, which suggests that humans are honoured and were actually made from clay. (S 29)

> The resources and instruments used when performing experiments – and then the accuracy of such tools – have resulted in new scientific theories being developed. (S 15)

The purpose of Question 8 was to investigate the subjects' views on whether or not science may be considered to be theory-laden. Seven of the subjects chose not to respond, and 12 gave answers in an effort to consider the two theories presented in the question. Three of these respondents supported the two theories, while another two supported just one. Another subject supported neither theory:

> It is my opinion that both theories are credible, whether a massive meteor or volcanic eruptions. Both can be viewed as rational and as affording credibility to extinction and its causes. (S 1)

> Volcanic eruption might be seen to be plausible when considering that the surface of the earth was experiencing evaporation. If we were to consider Asia and Africa, both were connected and attached. But then, if we think about the Arabian Peninsula, this was part of Africa. Some scientists have considered volcanoes to be responsible, and I hold the same view, especially when you think about the Red Sea as having a number of different volcanoes, and the western coast of Saudi Arabia also having volcanic soil. (S 9)

> There's no evidence to support either a volcanic eruption or a meteor strike. Nothing. (S 20).

> The other six respondents considered the type of data utilised:

> We would need to examine the remaining aspects and relics of meteors, volcanoes, etc. (S 33)

It is noteworthy that all of the subjects quoted above considered the theories that were presented in Question 8 without examining the more important aspects of the question, such as why there are differences between theories. Three of the respondents considered that scientists arrived at their own conclusions by gathering evidence and examining data. On the other hand, one of the respondents maintained that different tools may be responsible for different theories:

> There are different theories of extinction because of the different tools applied when analysing extinction causes, and the different periods of time when research was carried out and the duration of such studies. It is sensible to consider that changes in natural circumstances and topography not only were apparent but should be taken into account. (S 15)

Nine of the subjects considered the presence of different theories to be due to different theories being unstable hypotheses:

> There is a need to recognise that these are hypotheses. Nothing more. And so it would be far more reasonable to identify such difference, especially when considering there is never anything constant. We are talking about events that happened 65 million years ago! There is therefore a need for hypotheses to be devised and presented that are at least somewhat correct. (S 5)

Only three students recognised differences between theories as being due to the preconceived ideas of scientists:

> There are differences from one scientist to the next, with different theories acceptable when considering their dissimilar scientific philosophies. (S 11)

The VNOS-C and Semi-Structured Interviews: Science is Empirically Based

The purpose of Question 1 was to establish the ideas of the subjects on science. The results suggest that ten subjects recognised science as being knowledge. In contrast, six subjects considered science to be a human activity. Another two subjects held the view that science is made up of a combination of both human activity and knowledge:

> Garnering miscellaneous knowledge. (S 2)

> It is a human activity. (S9)

> Science could be viewed as knowledge and human activity. Both. (S 35)

Importantly, however, six of the participants considered science as being a place for theories and facts, and the validation of such. Science was determined by three of the subjects as being identical to understanding and thought, in line with their own view. Another three subjects recognised science as academic teaching comprising hypotheses, laws, and theories. Only three subjects considered science as depending on experiments, whereas two viewed science as being acquired through studying nature.

Regarding the difference between science and other types of knowledge, three of the subjects did not respond. Thirteen subjects considered the difference between religion and science to be greater than the difference between science and any other field of knowledge; they emphasised factors of change, testability and stability. The subjects indicated their cultural and religious backgrounds when providing the following statements:

> Since the time we were created by Allah, religion has been invariable. But then consider science, which changes all the time. (S 10)

One student provided further explanation when probed during the semi-structured interview:

> Scientific specialisations should be recognised as a human activity rather than being revealed by God. But then the Quran remains consistent and therefore unchanged. (S 4)

Eight other subjects considered scientific facts to be verifiable in line with other fields of knowledge. Seven subjects considered other sciences as being focused on the adoption of science for practical purposes, whereas four maintained that science can be differentiated through thought and insight, as opposed to other knowledge divisions, such as those in which memorisation is most dominant.

The VNOS-C and Semi-Structured Interviews: Science as dependent on human inference, creativity, and imagination

The purpose of Question 10 was to establish the subjects' ideas on the role played by creativity and imagination in the professional lives of scientists. Ten of the subjects did not answer the question, and three subjects stated that scientists do not make use of imagination or creativity:

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> It is possible that creativity is surplus. But there is a need to make efforts and suggest solutions in order for questions to be posed and answered. (S 22)

> Imagination or creativity is not used by scientists; they depend on scientific concepts and theories, which they progress and enhance. (S 32)

These three respondents provided answers justifying why scientists did not use creativity or imagination; reasons included that scientists depend on scientific research, that they attempt to provide answers to questions, and that they apply concrete, testable theories. In contrast, most of the subjects (*N* = 22) considered that scientists make use of both imagination and creativity.

> Scientists definitely use imagination and creativity; they are known to have higher-order thinking skills. These include imagination and creativity. (S 28)

These 22 respondents also provided rationalisations for their perspectives. Some considered that scientists need to utilise imagination and creativity in order to arrive at new scientific ideas.

> Scientists utilise creativity and imagination in order to satisfy their scientific purposes. (S 16)

> Creativity and imagination among scientists go some way to explaining various unknown phenomena, how they first came to light and when they were first presented. (S 11)

Some of these participants considered that scientists utilise imagination and creativity when completing their own experiments. One of the interviewees stated:

> Without question, creativity and imagination are used by scientists before they even devise hypotheses or carry out experiments, or predict findings, and they use their imaginative ideas as validation after the experiment. (S 14)

Another example provided by the respondents was the history of science, in which imagination was recognised as a key aspect underpinning scientific development and qualitative scientific contributions. Various fields were mentioned by the respondents, including biology, chemistry, classical physics, and space:

> Take Newton as an example, who identified the link between gravitational forces and bodies, which he did when the apple fell from the tree. This ignited his imagination and led to him developing insight into gravitational force. (S 4)

> Imagination has been used by scientists whenever they contrast atoms and electrons alongside the solar system. Think about it. (S 29)

> Recognising the moon and then walking on it was nothing more than imagination once! But now it's been done, and that wouldn't have been possible without creativity and imagination. (S 15)

> Imagination is fundamental to scientists. Take genetics, genetic inheritance, and the transmission of genetic traits, as highlighted by Mendel: he was creative in hybridisation, and ultimately was successful in achieving new and never-before-considered horizons in genetics. This led to scientific revolution! (S 30)

Only 19 participants in the sample answered the questions that centred on the various phases through which creativity and imagination can be implemented. These 19 subjects maintained that scientists utilise both creativity and imagination when practicing science. Twelve subjects considered imagination and creativity to be utilised only in the designing and planning stages. On the other hand, four subjects believed these traits to be utilised only following data collection. Another three subjects stated that creativity and imagination are utilised across all stages of science: beginning with research problems, design, and planning, and continuing until conclusions are reached.

The VNOS-C and Semi-Structured Interviews: Science as Culturally and Socially Embedded

The purpose of Question 9 was to establish the subjects' ideas on whether there may be an overlap between scientific, cultural, and social values. Seven subjects chose not to answer the question. Fourteen subjects maintained the non-existence of an overlap between science and the cultural values of science:

> Facts associated with life or the environment are not linked to the society of the individual person. (S 32)

Nonetheless, all of the respondents agreed on why such views are adopted – that is, because science is of a universal nature:

> Science is universal, and therefore extends far beyond the parameters of culture and society. Cloning and embryology provide valuable examples of this. (S 19)

> Science is universal, meaning that laws going against social values aren't permitted. (S 4)

> Science is universal, and therefore does not represent any social values of any country, people, or even society. (S 23).

In contrast, ten of the respondents maintained that science does, in fact, overlap with cultural and social values, and indicated religious factors to justify their views.

> Without question, science represents cultural and social values owing to the fact that experiments might go against belief, faith, and religion. (S 14)

> Various divisions of science are not aligned with Islamic teachings, as in the case of the theory of evolution. Such a theory is not adopted by Muslims. (S 19)

Other respondents maintained that an overlap is due to the complementary link that can be identified between society and science. These respondents (N = 4) considered science to be universal in nature, although they maintained that it reflects cultural and social values:

> Science forms the foundation of society. In my view, there is a complementary link; no science can be without cultural and societal values, and similarly, if there is no science, there are no social values. (S 16)

> Without question, science highlights social values. If we are to get on board with the idea of Darwin's theory of evolution, this goes against the Islamic faith, which subsequently impacts cultural and societal values – and these have formed the foundation of our upbringing and lives. Furthermore, science is universal when considering that there is no link between it and scientists, such as the Jewish Newton. Of course, he is not of the same religion, faith, or nationality, but it remains that his contribution of laws are widely applied in our modern-day society. (S28)

> The Nature of, and Differentiation to be Made between, Scientific Laws and Theories

The purpose of Question 5 was to address the difference between scientific laws and theories. Four subjects did not reply to this question, while another subject emphasised that there was no difference between laws and theories. However, the justification that the latter subject provided was contradicted by the subject's statement:

> There is no difference between the two, although a scientific theory seeks to provide an explanation of particular behaviours, whether from a philosophical or theoretical standpoint, whereas scientific laws explain patterns through mathematical problems that might actually need to be applied. (S 11)

However, 30 other respondents maintained that there was a difference between scientific law and scientific theory, albeit with differing justifications. Two subjects did not describe any differences between laws and theo-

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ries; 12 subjects suggested that scientific law is constant, in contrast to scientific theory, which can be changed and fluctuates. This comment was obtained during an interview:

> There is a difference between a scientific law and a scientific theory, with a scientific theory being changeable; a law, on the other hand, does not change. It is a law. It is absolute. (S 32)

Five of the respondents stated that laws are not as complicated as theories. Four subjects considered that a scientific theory presents the most valuable events and observations, whereas a law is a statement that predicts events in nature. Four of the subjects suggest that a scientific law can be expressed through a mathematical formula, whereas a theory may be considered a law's verbal expression. Two subjects considered the difference between theories and laws to be that the validity percentage is low in a theory, but high in a law:

> In scientific law, the likelihood of error is low, whereas in the case of scientific theory, it can be high. (S 12)

> In scientific law, the error percentage is 0.99%. It's as simple as that. (S 13)

Two of the subjects noted that when laws and evidence are accessible, theories develop to become laws; this comment presents a clear difference between laws and theories and highlights the presence of a sequential hierarchical correlation:

> Scientific theory can be enhanced and developed so that it becomes a scientific law. (S 15)

Only ten respondents provided examples to support their answers. Two of these examples were considered to be irrelevant, such as when considering mathematical formulae, and so forth. Other examples that were provided were accurate, including those that centred on the atomic theory, immersion law, the theory of relativity, Newton's law, Mendel's theory, and the rate law.

The VNOS-C and Semi-Structured Interviews: The Identifiable Difference between Inference and Observation

The purpose of Question 6 was to investigate the subjects' understanding of the link between inference and observation. This was achieved by examining the first aspect of the question, which centred on the certainty held by scientists regarding their views on the atom and its contents. It is notable that 17 subjects within the sample did not provide an answer to the question; however, 15 subjects provided answers stating that scientific knowledge has not only been asserted, but also proven and validated through various experiments, research, and students ($N = 8$).

> Studies, experiments, laboratories, research… All of these have helped scientists to ensure their own certainty of the atom. (S 1)

Two subjects cited modern devices and four subjects mentioned microscopes as confirming the presence of the atom. In contrast, one respondent emphasised the use of predictions, imagination, and studies:

> Studies and predictions, and possibly scientific imagination, have all helped contribute. (S 2)

Another three subjects stated that scientists are not entirely certain about the atom because these beliefs remain mere hypotheses.

> Scientific knowledge is simply opinion or hypothesising. It is temporary and can change. (S 3)

Most of the subjects (26) in the sample chose not to answer the question about the evidence that has resulted in scientists creating the conception of an atom. However, five subjects did note that scientists have used the Milky Way Galaxy as an example when describing the atom. Two other subjects noted that scientists have used fruit as an example to describe the atom, while another two mentioned the conception of an atom as determined through atomic spectra:

> There is not much difference between the Milky Way Galaxy and an atom. In essence, the sun may be seen to be the nucleus, whereas the atomic orbitals are the orbitals. (S4)

> The present conception of an atom has been devised through evidence focused on fruit, with fruit recognised as having an internal nucleus, with scientists therefore drawing the conclusion that everything has a nucleus. And we are well aware that a nucleus holds a positive charge. (S 4)

> Physicists have applied the atomic spectra to establish the overall constitution of the atom. (S 5)

The VNOS-C and Semi-Structured Interviews: The Myth of the Scientific Method

The purpose of Question 2 was to reveal the subjects' conceptions of scientific experiments. Six subjects chose not to answer the question, while 16 subjects considered the completion of an experiment to be necessary in order to establish what has been examined, or develop a theory into practice. This comment was made in one of the interviews:

> An experiment could be carried out to provide a practical application of what has been under examination or determined through experience, knowledge, or skill, with effort centred on seeking to identify what might not have been determined through theory. (S 11)

Another six subjects, however, provided answers that centred on the overall linguistic meaning of the term 'experiment'. In particular, these subjects used terms such as 'assert', 'validation', and 'test'. Interestingly, six subjects viewed experiments as a group of different processes. One of the subjects presented this view of what may be recognised as a scientific experiment:

> An experiment could be defined as a particular that seeks to establish a fact or otherwise present evidence to the contrary. It can be incredibly valuable in validating an event through variable control or isolation. (S 4)

The purpose of Question 3 was to establish subjects' perception of the overall value of scientific experiments for scientific knowledge development, and of how such development may rely on scientific experiments rather than on any other means of obtaining scientific findings. Only one respondent held the view that scientific knowledge does not warrant experimentation:

> Scientific knowledge development should not warrant the conduction of experiments. (S6)

In contrast, 34 of the respondents considered that scientific knowledge requires the completion of experiments. This finding suggests that most of the respondents involved in this research do not hold accurate views of how scientific knowledge may be acquired by scientists. Furthermore, only 20 of the subjects provided examples to support their answers. It is the researcher's opinion that in order to expand further on the lack of clarity in the views of pre-service science teachers regarding the need for scientific experiments, it would be necessary to obtain examples from the respondents. This comment was obtained during one of the interviews:

> The presence of the chemical element Uranium was not recognised in the past, but, thanks to modern-day developments, the element was identified. (S 7)

The majority of the respondents provided examples that related to Newton's three laws of motion. One respondent provided an example to back up the answer that with the development of knowledge, it becomes increasingly necessary to complete experiments, and that there is a positive link between the development of knowledge and experimentation:

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> The development of knowledge warrants the need to complete experiments. As an example, take Newton who, when experiencing the apple falling, suddenly stumbled across the realisation of gravitational force. (S 17).

> Baumgartner is known to have come up with his theory regarding the speed of sound when skydiving. He did this at an altitude of 36 576 m with the aim of breaking the sound barrier and the record for the highest-ever jump. Felix was therefore successful in extending his knowledge through experiments, which shows that constant laws can be extended through knowledge development. (S 15)

Importantly, however, two of the respondents gave examples that went against their answers, which stated that scientific knowledge development warrants the completion of experiments. One of these respondents stated that zoology can be developed through body dissection, despite the fact that observation is warranted in this regard and not experimentation. The other subject recognised that observation was needed when examining the behaviours of organisms:

> Comparative anatomy experiments could be carried out to establish the presence of internal biological systems or otherwise to determine whether organisms have particular systems. (S 19)

> Any experiment carried out has the potential to extend the knowledge base, with experiences in this regard proving valuable in knowledge development. Through examining an organism's behaviour in various different settings, for example, we can come to establish that behaviour in a natural environment might differ from that exhibited in non-natural surroundings. (S 8)

The purpose of Question 7 was to validate the application of observations by scientists in their pursuit of scientific knowledge. Ten subjects did not provide an answer, while 25 subjects considered that scientists direct a great deal of emphasis towards classification. The answers provided by the respondents were associated with the second part of the question, which emphasised the provision of evidence applied by scientists when seeking to establish the identity of those established. A large number of the subjects (N = 16) provided generalised insights without making any reference to observation; these answers tended to centre on examining colour, external characteristics, and external properties, for example, although certain recognised scientists place more emphasis on genetics and genes when classifying organisms, rather than on any other traits.

> Types were classified in line with taxonomy, in consideration to their recognised shared traits. (S 15)

Nonetheless, it was held by two subjects that scientists carry out experiments to classify organisms:

> Scientists carry out experiments to complete classifications in order to categorise organisms, as can be seen when evaluating similar formation and characteristics. (S 14)

One of the students provided several different examples of research, whereas another communicated the view that studies and experiments should be used in combination. On the other hand, four of the respondents suggested the use of observations by scientists:

> …through the completion of organism observations in relation to formation and the way in which they co-exist, as well as by carrying out observations on the surroundings and community of organisms. (S 23)

> One of the students mentioned observations and experiments:

> Observations of organisms can be carried out in order to validate similarities in various regards, such as external construction, movements, and type, for example, with experiments carried out in order to validate their views on types. (S 32)

Discussion

The research findings showed that the understanding pre-service science teachers in the KSA have of the NoS is both basic and inadequate. The responses to the MOSQ questionnaire revealed that the majority of the respondents adopted a conventional perspective on theories and hypotheses. This particular finding aligns with the findings of Abu-Athera (2013), who notes that Saudi pre-service teachers perceive laws as being far stronger than scientific theories. Like pre-service science teachers in other contexts, the majority of the sample in this research was found to hold misconceptions on hypotheses and the role they play (Abd-El-Khalick et al., 1998; Buaraphan & Sung-ong, 2009).

The responses to the VNOS-C suggested that only eight of the subjects held informed views on the difference between scientific theories and laws. Such a large number of uninformed answers may be due to a weakness in addressing such concepts within the science curriculum books that are available in the KSA, as was suggested by Alshamarni (2012).

The pre-service science teachers considered in this work communicated a conventional view of scientific knowledge, and held the belief that scientific knowledge cannot be changed. The responses to the VNOS-C showed that the majority of the teachers in the sample consider that a scientific theory can be expanded further and developed, but does not change. One rationalisation for this finding may be that the teachers perceive theories as not being as valid or credible as laws, because laws are non-wavering and consistent, whereas theories can be changed. This perception became apparent when considering that two thirds (67%) of the sample considered that scientific theories could be developed into laws. Thus, the teachers in the sample perceive laws as being mature, whereas theories are not. This result goes against the work of Buaraphan and Sung-ong (2009), who recognised the tentativeness of science or scientific dynamics as being well recognised by pre-service teachers in the Thai context.

The sample agreed that evidence gathering provides a greater degree of consistency in scientific knowledge. Regarding the responses to the VNOS-C, almost half of the subjects answered questions to validate their view that knowledge in science has been both verified and proven through the completion of experiments, research, and studies. Importantly, scientific knowledge was viewed as requiring experiments, which validate scientific knowledge through scientific data 'showcasing' the truth. As shown by Haidar (1999), pre-service science teachers consider that scientific knowledge is able to grow and develop, and that its expansion depends on observation.

The sample in this research considered that scientific frameworks would be devised and implemented following the completion of experiments. In the results of the VNOS-C, only one subject emphasised the use of predictions, imagination, and studies. Some of the subjects provided the example of the Milky Way Galaxy as a way of portraying the concept of the atom; atomic spectra were also suggested as a means by which the atom concept has been verified. Pre-service science teachers in the KSA were shown to be unable to differentiate between inference and observation; however, a proper understanding of this difference is fundamental if various theoretical and inferential entities and terms present in science are to be understood. Such entities might include atoms, genes, gravitational forces, magnetic fields, molecular orbitals, and species.

The myth of the scientific method was commonly identified in the views of the pre-service teachers in the sample, who considered that there is a predefined process to be adopted by scientists (Lederman et al., 2002). A number of the teachers stated that science follows a systematised approach, and that the various stages should be implemented in a particular order for scientific knowledge to be constructed and validated. Moreover, this research shows that the teachers disagreed with the statement that scientific methods and science are able to provide answers to all questions; this is predominantly because science, as a defined term, is associated with knowledge. In this vein, Haidar (1999, p. 808) noted that the Arabic word 'ilm', which is utilised in Arabic in an effort to provide a partner for the English term 'science', might actually be assigned a different meaning. That is, the meaning of 'science' in English might not be identical to the meaning of 'ilm' in Arabic (Haidar, 1999; Tymieniecka, 2010). This may be why three quarters of the sample held the view that scientific knowledge does not stem from experiments alone. Since 34 of the respondents considered that experimentation underpins the development of scientific knowledge, the research sample in general seems to lack insight into the ways in which scientific knowledge may be garnered.

Regarding the work done by scientists, many of the pre-service science teachers in the sample emphasised scientific objectivity, which is clearly founded on value-free and theory-free observation. For example, Question 8 of the VNOS-C, which suggests that scientists ensure an open-minded approach free from bias, and which is intended to investigate the subjects' views on whether science is theory-laden, achieved agreement from more than half of the sample. The findings aligned with the research of Buaraphan & Sung-ong (2009), which emphasised

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that a portion of the most commonly held bipolar perspectives pertaining to NoS are objectivity and subjectivity, theory-free and theory-laden, or value-free and value-laden. In the case of the majority of the sample, subjectivity was recognised as pivotal in the development and expansion of scientific ideas.

Most of the subjects considered that scientists do not make use of imagination or creativity when seeking to obtain scientific knowledge. However, creativity and imagination in the construction of scientific ideas was recognised by the majority of the sample (Abd-El-Khalick et al., 1998). Only 19 members of the sample answered the questions posed in the VNOS-C regarding when creativity and imagination might be utilised by scientists; these respondents considered that creativity and imagination are used by scientists in scientific practices. Twelve of the subjects, however, considered that these qualities are used only in the design and planning stages, while four considered that these qualities are used only during data collection. This result shows that the sample recognised that creativity and imagination are used at some point in the scientific process (Lederman, Lederman, Byoung, & Eun, 2012). However, some of the subjects considered that all the steps of the scientific knowledge development process benefitted from creativity and imagination (Yuenyong, 2010).

Regarding scientific enterprise, the sample adopted both conventional and modern perspectives on the link between technology and science, with roughly the same percentage of subjects holding each perspective. Therefore, differentiating between technology and science is likely a problematic task (Buaraphan & Sung-ong, 2009). Nonetheless, most of the subjects disagreed with the view that scientific enterprise is an individual enterprise. Similarly, most disagreed with the statement that culture, politics, and society do not influence scientific knowledge development. On the other hand, based on the results from the VNOS-C, a number of the subjects were found to consider that the overlap between social and cultural values and the sciences was non-existent. These answers revealed that the majority of the sample in this research does not have well-informed views regarding the degree of overlap between science, culture, and society (Alshamarani, 2012). More specifically, a number of the subjects failed to consider science as a social enterprise (Buaraphan & Sung-ong, 2009).

Conclusions

In light of these findings, it can be concluded that helping science teachers to acquire an adequate understanding of the NoS should be a basic requirement for professional development programmes for teachers. This research revealed that a significant number of pre-service science teachers need urgent assistance from relevant stakeholders, because these teachers hold uninformed conceptions of four aspects of the NoS: scientific knowledge, the scientific method, scientists' work, and scientific enterprise. These findings are consistent with the results of a great deal of research in local and global contexts. The involved stakeholders, such as science educators in both local (e.g. the Ministry of Education of Saudi Arabia) and global contexts should employ these findings as a basis for designing a professional development programme to help science teachers develop their understanding of the NoS. Including NOS in the science curriculum is not enough to ensure the effective teaching and learning of NOS. Pre-service science need well-designed NOS professional development programs teaching how to integrate NOS into their classrooms, including the related curriculum materials. The views and perceptions of science teachers regarding the NoS may influence the way in which they teach in a classroom environment. Furthermore, science teachers' understanding has been recognised as inadequate for teaching students about the NoS. Therefore, the NoS should be a critical component in the training of pre-service science teachers.

The findings of this research imply that the most valuable approach to develop students' thinking is to provide them with the opportunity to discuss their ideas, investigate the limitations associated with science, and discover how scientific knowledge may differ from other types of knowledge. Furthermore, students should be given the opportunity to discover the importance and value of science as a way of explaining phenomena, and should be encouraged to develop an awareness of the impacts of science on society. It may also be worthwhile to include appropriate topics and attitudes in the educational programs in pre-service teacher preparation in a way that will help them to understand the NoS and that will highlight appropriate classroom practices during the mini-teaching and education process.

The need for teachers and students to learn about the NoS should be recognised as critical across the various levels of science education in the KSA. Further work is required to obtain an in-depth insight into the perspectives of Saudi science teachers on teaching the NoS in a classroom environment, and on how teacher-education pedagogies can affect and influence how the NoS is taught. Another implication stemming from this research is the need to examine the link between the views relating to the NoS that are held by pre-service teachers, and their teaching practices. This question remains somewhat unanswered in the existing literature, so more focus should be directed to this arena, particularly in the context of the KSA.

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