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VIEWS ON NATURE OF SCIENCE AND ATTITUDES TOWARD TEACHING NATURE OF SCIENCE AMONG CHEMISTRY STUDENTS IN SAUDI UNIVERSITIES

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Abstract. *Understanding nature of science (NOS) is a fundamental goal in science education standards. Due to the role of specialised and educational teachers' preparation programmes in developing their NOS concepts, this study aims to identify views on NOS and attitudes toward teaching NOS among Saudi undergraduate chemistry students and the differences between them according to their academic level and university affiliation. Views on science and education questionnaire were distributed among chemistry students in eight universities. Results found inaccurate views regarding the differences between theories and laws, and that pertaining to well-trained scientists as being detached from personal, social, and cultural values. Half of the sample disagreed on inventing theories and laws and the diversity of Scientists' methods and also rejected teaching a variety of methods and the influence of personal beliefs on Scientists' observations. No significant differences among students' views by academic level or universities were found, except that second-level students have more informed views than fifth-level students, and the UHB and JU students' views were more informed than IMSIU students. The authors recommend developing those NOS concepts which students had shortcomings in the sequential teachers' preparation programmes and suggest recognising chemistry department faculty members' attitudes to developing students' NOS concepts.*

Keywords: *attitudes toward teaching NOS, nature of science, university chemistry students, views on science and education (VOSE).*

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Introduction

The broad effects of science can be clearly demonstrated in life, such as engineering designs and techniques driven by scientific arguments and practices (Purzer & Quintana-Cifuentes, 2019), and the philosophical ideas arising from scientific development. For example, Einstein relativity, and Heisenberg uncertainty are cognitive theories that have contributed to the identification and scope of scientific knowledge (Shamsuddin, 2009).

Throughout history, the development of philosophical ideas about science have contributed to the growth of scientific knowledge and the occurrence of scientific revolutions (Alshamrani, 2021). For example, Bacon, in developing the inductive approach, relied on the theory of knowledge, whose ideas included the emergence of absolute truth from sensory experience, which contributed to several scientific achievements in classical mechanics (Shamsuddin, 2009). The contribution of the philosopher Kant's vision about the interaction between the mind and the data of the senses, Popper's revelation that the premise of scientific research is a hypothesis in the mind of the scientist, and Howell's study of the inductive approach led to the emergence of the hypothetical deductive approach which contributed to the quantum mechanics revolution in the 20th century (Alkhouli, 2000). This describes and explains the movement of electrons and energy levels in the structure of an atom and the dual nature of particles, it also produced a new field in chemistry known as quantum chemistry that employs quantum models to predict and explain chemical phenomena (Seifert, 2020).

Nature of science (NOS) expresses the characteristics of scientific knowledge derived from the processes or methods used to develop scientific knowledge (Lederman & Lederman, 2012), or the values and hypothesis that constitute scientific knowledge (Lederman, 2007). According to Alshamrani (2021), the term NOS emerged in the context of science education to meet the philosophy, history and sociology of science, and from which "students learn how science works, the nature of its functions, how to generate and test scientific knowledge, and how scientists do their work" (McComas, 2014, p. 221). Science education documents emphasised the reinforcement of these concepts among learners as a main goal in science education (Education and Training Evaluation Commission, 2019; NRC, 1996; NGSS, 2013).

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Aspects of NOS (Chen, 2006; NSTA, 2020; Schwartz & Lederman, 2002) addressed the tentativeness of scientific knowledge and its impact by subjective, social, and cultural factors. In terms of the nature of scientific observation, scientists can interpret the same experimental data differently based on previous expectations or notions. Moreover, the validation of scientific knowledge depends on empirical evidence, and its acceptance is affected by subjective aspects such as intuition; it is connection to the Paradigm, the impact of the reputation or academic status of the theory proposers, and the theory's simplicity. On the other hand, the methods of scientists in scientific research vary and are not limited to one global or unified scientific method, such as the use of imagination alongside logic and previous knowledge. According to (Chem, 2021) imagination is frequently used in chemistry; because chemical reactions occur at the level of molecules, atoms, and subatomic particles. The nature of scientific advancement is also described as the revolutionary approach in which a theory is replaced by a new one, or the cumulative approach that highlights the retention of an old theory, or the evolutionary approach that is close to accuracy and complete (Chen, 2006; Schwartz & Lederman, 2002). For example, Mendeleev developed the periodic law that predicts physical and chemical properties of the elements according to their arrangement by atomic number. Although Moseley replaced "atomic weight" with "atomic number" and despite the insights and effects of quantum theory, it is still a central law in chemistry, and does not need to be reduced to theories of quantum chemistry (Christie & Christie, 2000).

One concept of NOS relates to the difference between laws and scientific theories. They are two different kinds of knowledge; laws describe observed patterns in nature and predict what has not yet been observed, while theories explain natural phenomena and their laws. It is worth noting that theory cannot be turned into law, and scientists create theories and laws to explain and describe empirical evidence (Chen, 2006; Schwartz & Lederman, 2002). Therefore, previous theories may be replaced or developed, as was the case with the development of theories about the structure of the atom, and Transition State Theory. Although one of the features of a law is accuracy, Ellis points out that violating accuracy is due to an epistemic rather than existential justification, as the properties of its entities may not be verified accurately. In fact, the initial calculation of the electron's charge was inaccurate. Despite continuous efforts to develop more accurate calculation methods, many laws and theories were built based on the old way of calculating (Christie & Christie, 2000).

Some characteristics of the laws and theories of chemistry may differ from the characteristics of the laws and theories of classical physics, which are often inferred by philosophers of science. This is explained by the different complexity of the systems, whereas a competitive feature prevails in theories of chemistry. Arrhenius', Lowry', and Lewis' theories offer different explanations for acids and bases. Moreover, the Valence Bond Theory and Molecular Orbital Theory provide different explanations for chemical bonds. As a result, the chemist can take a pluralistic attitude towards the different theories (Christie & Christie, 2000). In addition, "the Periodic Law seems not to be exact in the same sense as are laws of physics, for instance Newton's laws of motion" (Erduran, 2009, p. 9). It is worth noting that epistemological properties of laws and theories are connected in chemistry and physics when they are related to phenomena studied under the fields of physical chemistry or the physics of chemical systems, such as ideal gas laws, and thermodynamics (Christie & Christie, 2000).

According to Kovac (2012), few undergraduate chemistry students know how chemical theories have developed in the twentieth century. Scientists and science learners realise NOS through scientific practices, known as implicit method. Furthermore, educators emphasise the need to plan to explicitly reinforce science concepts, because they are developed as a secondary learning product through participation in scientific practices (Abd-El-Khalick & Lederman, 2000; NSTA, 2020). Understanding NOS contributes to supporting the learning of science content (McComas, 2014). Evidence indicates that having philosophical views of chemistry has a positive impact on learners' attitudes and the quality of their learning (Erduran, 2013). Moreover, understanding NOS contributes to identifying the relationships that exist between science growth and technology, mathematics, culture, society, politics, psychology, and in developing knowledge of the ethics and practices of science among learners, and understanding the strengths and shortcomings of scientific knowledge, and appreciating the value of science (McComas, 2014). For example, quantum theory calculations of molecular structure provide approximate data. To address this cognitive shortcoming requires the development of several measurement techniques (Christie & Christie, 2000).

Local and global interest in understanding the views of university students about NOS is reflected in several scientific studies whose results ranged from the presence of shortcomings in participants' views about most aspects of NOS among pre-service science teachers at Al-Jouf University (Alanazi, 2018), and in preparatory year students in scientific and engineering disciplines at King Saud University (Alshamrani, 2012). Moreover, some studies showed

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a transitional level of views ranging between informed and naive among physical chemistry students at a Scottish university (Agustian, 2020), an average of informed views about NOS among female students of scientific disciplines at King Saud University, and an average trend towards teaching issues related to NOS (Alahmad et al., 2019).

Given that views about NOS is one of the components of scientific literacy (Bybee, 1997; NSTA, 2020), many researchers are interested in investigating university student perceptions, especially if they have positive impacts on learning (Erduran, 2013; McComas, 2014; NSTA, 2020). Moreover, the structure of teaching beliefs among chemistry teachers is formed by views about NOS or the philosophy of chemistry and learning and teaching (Bryan, 2012; Erduran, 2013). It is worth noting that specialised and educational preparation programmes for science teachers contribute more clearly to developing their views about NOS (Dipietro & Walker, 2016), and that changing teachers' views about NOS is not possible through short-term professional development programmes (Kartal et al, 2018). Having informed views about NOS among science teachers is one of the basic criteria for developing an understanding of NOS among students (Abd-El-Khalick & Lederman, 2000), and that understanding pluralism in the philosophical perspective of science leads to different cognitive and teaching patterns in chemistry education (Erduran, 2013).

Research Problem

Saudi Vision 2030 aims to develop a solid educational foundation for all and support scientific research to better understand scientific issues and innovate solutions. The scientific movements in any society result from the scientific literacy of its members. One aspect of scientific literacy includes understanding NOS, a fundamental goal in national and international science education standards.

There are inaccurate views expressed by chemistry teachers about certain concepts of NOS (Alahmad et al., 2021; Omar & Alsubaie, 2016), which may negatively affect their teaching beliefs (Bryan, 2012; Erduran, 2013), and on their role in building investigative learning environments that simulate the practices of scientists (McComas et al., 2020). Given the key role of specialised and educational teacher preparation programmes in developing views of NOS (Dipietro & Walker, 2016), Alahmad et al. recommended identifying NOS concepts among university science students. In fact, on the one hand, final level university students can be considered as inputs to the profession of teaching chemistry in pre-university or university education (2019). On the other hand, revealing the concepts of NOS among undergraduate university students of primary levels contributes to directing scientific education specialists to reinforce the strengths and weaknesses of integrating NOS into pre-university education science courses (Alshamrani, 2012).

Considering that aspects of NOS are broad (Erduran, 2013), most of the previous research has identified science students' views on NOS without examining the differences between them according to specialisation (Alahmad et al., 2019; Alanazi, 2018; Alshamrani, 2012; Sumranwanich & Yuenyong, 2014; Yenice, 2015). Irzik and Nola pointed out that the nature of observation in chemistry differs from that in botany, as it focuses more on atomic phenomena (2011, as cited in Alshamrani, 2021). And some characteristics of the laws and theories of chemistry may differ from the characteristics of the laws and theories of classical physics (Christie & Christie, 2000), which may, in turn, affect students' views about aspects of NOS according to scientific specialisation. Furthermore, building on the importance of the cultural context in explaining NOS, the Islamic perspective within the Saudi context integrates the physical and mental sources of knowledge and is based on belief in the unseen. Knowledge is relative and variable, except for that which is revealed by one of the two revelations: the Holy Quran and the Sunnah, which are fixed and require reflection (Alsalami, 2021), this source included a description of a number of scientific phenomena, which may affect the perception of NOS compared to other research contexts.

Accordingly, there is a need to recognise the views of chemistry students about NOS and attitudes toward teaching NOS and the statistically significant differences by university and academic level. In this study, such differences by university and academic level were obtained from eight universities across different regions of the Kingdom of Saudi Arabia. Of note, most of these universities have not previously revealed their students' views about NOS.

Research Questions

1. What are chemistry students' views about NOS in Saudi universities?
2. What are chemistry students' attitudes toward teaching NOS in Saudi universities?
3. Are there statistically significant differences in views about NOS and attitudes toward teaching NOS among chemistry students from different universities?

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4. Are there statistically significant differences in views about NOS and attitudes toward teaching NOS among chemistry students at different academic levels?
5. Are there statistically significant differences between views about NOS and attitudes toward teaching NOS among chemistry students?

Research Methodology

General Background

For this quantitative study, the researchers used the questioning method: "A large sample of the research community questioned to describe the studied phenomenon, in terms of its nature, and the degree of its existence" (Alassaf, 2016, p. 211). The Views on Science and Education (VOSE) questionnaire of Chen's study (2006) was adopted, which concentrated on seven essential concepts of NOS: scientific progress, tentativeness, scientific observation, methods, laws and theories, imagination, validation, objectivity, and subjectivity, to identify the views of a sample of 501 Undergraduate chemistry students from eight Saudi universities and at different academic levels. A review of the study plans of the chemistry departments of these universities revealed that such plans did not include similar courses or courses on NOS and history of science and science education. The researchers collected the data during the 2021 academic year in cooperation with the university deanships of scientific research and their chemistry departments. Moreover, the sample was limited to female chemistry students due to the separation between females and males in most Saudi Universities.

Population and Participants

The research population comprised chemistry students from eight universities located throughout the North, South, Central, East, and West of the Kingdom of Saudi Arabia. These universities are King Saud University (KSU), Imam Muhammad Ibn Saud Islamic University (IMSIU), Hafr Al-Batin University (UHB), King Abdulaziz University (KAU), Taif University (TU), Al Jawf University (JU), King Khalid University (KKU), and Bisha University (UB). According to the chemistry departments statistics requested by the researchers, the population included 3091 chemistry students, of which only 501 responded. Table 1 shows the population and the distribution of participants according to their university. Table 2 presents the distribution of participants according to academic level.

Table 1
Population and the Distribution of Participants According to their University

University	Population	Participants	
		n	%
King Saud University (KSU)	125	35	28
Imam Muhammad Ibn Saud Islamic University (IMSIU)	274	56	20.4
Hafr Al-Batin University (UHB)	600	166	27,6
King Abdulaziz University (KAU)	600	43	7.2
Taif University (TU)	542	63	12
Al Jawf University (JU)	230	68	29
King Khalid University (KKU)	604	56	9.2
Bisha University (UB)	116	14	12
Sum	3091	501	16.2

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Table 2
The Distribution of Participants According to their Academic Level

Academic level	First-year student		Second-year student		Third-year student		Fourth/final-year student	
	First	Second	Third	Fourth	Fifth	Sixth	Seventh	Eighth
n	96	36	56	25	98	22	100	68
%	19.2	7.2	11.2	5	19.5	4.4	20	13.5

Instrument and Procedures

The researchers used Chen's (2006) VOSE questionnaire to assess the views regarding NOS and attitudes toward teaching of undergraduate students and pre-service and in-service teachers. The instrument concentrated on seven essential concepts of NOS: scientific progress, tentativeness, scientific observation, methods, laws and theories, imagination, validation, objectivity, and subjectivity. The questionnaire consisted of nine questions about views on NOS and four about attitudes toward teaching NOS. Each question in the questionnaire was followed by many items representing different philosophical positions, which were rated by respondents on a two-point scale (approve or reject).

The researchers calculated the internal consistency of the questionnaire using Pearson's correlation coefficient after distributing it to a sample of 30 chemistry students. The results fell between .893 and .405 for views on NOS and between .934 and .890 for attitudes toward teaching NOS. These values indicate that each item had a medium to high internal correlation, confirming the reliability of the questionnaire (Abu Hashem, 2012). A Cronbach's alpha was calculated at .80 for views on NOS and .91 for attitudes toward teaching NOS, reflecting high reliability (Allam, 2007).

A brief description of the study objective, procedures, and questionnaire was sent to the Human and Social Research Ethics Committee of King Saud University for approval. Approval was granted, and the approval number is (4-67-319760). The study objectives at the front of the questionnaire were explained to the respondents and assured them that confidentiality of data would be maintained. A letter was sent from the Deanship of Scientific Research at King Saud University to the deanships of scientific research in the universities requesting that the questionnaire be sent to their chemistry department students. The questionnaire was sent through the deanships of either the information technology or chemistry departments. The letter did not include any mandatory formula for answering the questionnaire.

Data Analysis

Descriptive analysis was performed based on frequencies, percentages, and means to identify the chemistry students' views on NOS and attitudes toward teaching NOS. The student's acceptance of positive statements is coded as 1. Their rejection is coded as 0 for paragraphs that contain naive conceptions of views on NOS (e.g., 2c, 2d, 3c,3e, 7a, 7b, 8c, 8d, 9a, 9b, 9f), and attitudes toward teaching NOS (e.g., 11a,11c, 12c, 12d, 12h, 13c, 13d). When only the mean of the axis is calculated, approval is coded as 0, and rejection is coded as 1. A one-way analysis of variance was conducted to identify the differences between views by academic level and university. Additionally, Scheffe and Tukey's methods were used for dimensional comparisons. A paired sample t-test was conducted to identify the differences between views about NOS and attitudes toward teaching NOS among chemistry students.

Research Results

The results indicated that 53% of university chemistry students agreed concerning how the scientific theory is approved by the scientific population. Results showed a neutrality of 78.65% in approving two different theories of a phenomenon given that they are derived from different points of view and are likely to be correct, followed by an objectivity of 69.9% in approving scientific theories that are based on empirical evidence. Moreover, the statements with the least percentage approval were subjectivity, such as the effect of the authority and academic

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status of the theory's proposers at 46.9%, followed by the simplicity of the theory at 46.3%, acceptance of the theory based on its connection to contemporary scientific theory at 43.7%, 45.5%, and using intuition to make judgments on the theory at 37.1%.

Results revealed that 73.8% of university chemistry students have informed views about the nature of scientific advancement, where their approval of the scientific advancement's revolutionary or cumulative nature at 72.3%, which highlights the preservation of the old or evolutionary theory at 75.8%, and close to precision and perfection at 73.3%, evidenced similar levels.

73.9% of university chemistry students held informed views related to the influence of social and cultural values in the direction of scientific investigations and their subjects. However, inaccurate views of university chemistry students appeared around the detachment of well-trained scientists from these values at 74.8%. Results indicated that the views of university chemistry students regarding the nature of observation were inaccurate and contradictory. 67.5% of students agreed that different beliefs affected a scientist's observations, while 64.1% mentioned that subjectivity cannot be avoided despite the efforts of scientists to employ methods to improve objectivity. However, an inaccurate perception appeared around the ability of scientific training to enable scientists to give up personal values at 82.4%, and that the observations will be similar because they are based on empirical facts at 85%.

The views of university chemistry students about scientists' use of imagination in scientific research were contradictory. 72.5% of students agreed that imagination is an important source of innovation, and 69.5% answered that scientists may use their imagination to varying degrees in scientific research. However, 81.4% of students argued that imagination may lack reliability, and 71.8% mentioned that it may not align with the logical principles of science. Moreover, results showed that 53.6% of university chemistry students did not agree with the diversity of scientists' methods in scientific research, while 78.6% accepted scientists' use of the universal scientific method.

Regarding the views of university chemistry students about the knowledge of theories and laws, they agreed with the statements that represent scientists' discovery of the theory, either because the idea already existed before being explored, at 85.6%, or because the idea was based on empirical facts, at 86.0%, which is higher than the percentage of students' approval to the statements that represent the scientists' invention of the theories; either because such theories were created by the scientists themselves, 44.1%, or because they can be refuted, at 40.1%. Similarly, students agreed with the statements that represent scientists' discovery of the laws, either because scientific laws are based on experimental facts, at 85.6%, or because scientific law are out there in nature, and scientists just have to find them, at 81.4%, which is higher than the percentages of students' approval to the statements that represent the scientists' invention of the laws, either because scientists invent scientific laws to interpret discovered experimental facts, at 47.9%, or because there are no absolute in nature, at 43.7%. Furthermore, results showed inaccurate views about the difference between theories and laws at 72.1%; 50.9% of students agreed that theories and laws are different types of ideas that cannot be compared, while 96.4% argued on the possibility of turning a theory into a law after several examinations. Moreover, 94.6% of students believed that theories are not as decisive as laws.

The attitudes of chemistry students in Saudi universities toward teaching NOS showed that 83% of students agreed to teach the universal scientific method, while half of the sample (50%) refused to teach using a variety of methods. Moreover, 45.7% refused to teach about the influence of personal beliefs on the nature of the observation. 70.6% of students agreed to teach the relativity of scientific knowledge, and 73.2% agreed to teach the definitions of hypothesis, theory, law, and the relationships between them.

The findings revealed that the informed views of female chemistry students about NOS in different universities were generally at a similar level, ranging means between .50 -.58 (Table 3). In order to find out the significance of the differences, the value of "F" reached 3.66, which is statistically significant at a significance level of .01 since the associated significance level is .001. Through dimensional comparisons, it is clear that no differences existed between universities, except between the students of IMSIU and JU, in favour of the latter, and between the students of IMSIU and UHB, in favour of the latter.

Moreover, the positive attitudes of chemistry students toward teaching NOS, from the different universities, were generally at a similar level, with means ranging between .64 - .72 (Table 3). In order to find out the significance of the differences, the value of "F" reached 2.115, which is statistically significant at a significance level of .05, given that the associated significance level is .04. However, through dimensional comparisons, it can be concluded that there were no differences between the attitudes of chemistry students by university.

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Table 3
Means and Standard Deviations of Chemistry Students' Views of NOS and Attitudes Toward Teaching NOS According to their University

University	Views of NOS concepts		Attitudes toward teaching NOS	
	M	***SD***	***M***	***SD***
KSU	0.50	0.16	0.72	0.15
IMSIU	0.44	0.14	0.68	0.15
UHB	0.54	0.19	0.66	0.12
KAU	0.51	0.18	0.68	0.14
TU	0.56	0.18	0.65	0.11
JU	0.58	0.14	0.66	0.10
KKU	0.54	0.22	0.64	0.12
UB	0.56	0.13	0.66	0.06
Total	0.53	0.18	0.66	0.12

The results indicated that the informed views of university chemistry students about NOS at Saudi universities at different academic levels were generally at a similar level, ranging between .50 -.62 (Table 4). In order to find out the significance of the differences, the value of "F" reached 2.158, which is statistically significant at a significance level of .05, given that the associated significance level is .037. Through dimensional comparisons, it can be concluded that there were no differences between the views of university chemistry students by academic level, except the second-level students have more informed views than the fifth-level students.

The positive attitudes of chemistry students toward teaching NOS in Saudi universities at different academic levels were generally similar, ranging from .61 - .69 (Table 4). In order to find out the significance of the differences, the value of "F" reached 1.72, which is non-statistically significant at the significance level of .05, given that the associated significance level is .1. The positive attitudes of chemistry students toward teaching NOS in Saudi universities at different academic levels were generally at a similar level, ranging means between .61 - .69 (Table 4). In order to find out the significance of the differences, the value of "F" reached 1.72, which is non-statistically significant at the significance level .05, given that the associated significance level is .1.

On the other hand, the chemistry students' attitudes toward teaching NOS were better than their views about NOS at a significance level of .01, except for the second-level students, where there were no differences between their view about NOS and attitudes toward teaching NOS at the significance level of .05, given that the associated significance level is .57.

Table 4
Means and Standard Deviations of Chemistry Students' Views of NOS and Attitudes Toward Teaching NOS According to their Academic Level

Academic level		Views of NOS concepts		Attitudes toward teaching NOS	
		M	***SD***	***M***	***SD***
First-year student	First	0.52	0.16	0.66	0.13
	Second	0.62	0.18	0.63	0.11
Second-year student	Third	0.52	0.19	0.65	0.12
	Fourth	0.51	0.15	0.67	0.09

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Academic level		Views of NOS concepts		Attitudes toward teaching NOS	
		M	*SD*	*M*	*SD*
Third-year student	Fifth	0.51	0.18	0.66	0.13
	Sixth	0.50	0.13	0.61	0.14
Fourth/final-year student	Seventh	0.56	0.19	0.69	0.10
	Eighth	0.54	0.19	0.68	0.14
Total		0.53	0.18	0.66	0.12

Discussion

Building on the above-mentioned findings, it can be concluded that most university chemistry students have informed views about the nature of scientific advancement. This is consistent with the study of Alahmad et al. (2019), which showed that most university science students have informed views about the nature of scientific advancement, along with the study of Sumranwanich and Yuenyong (2014), which indicated that one-third of graduate students in science education have informed views of the cumulative and evolutionary NOS.

The views of university chemistry students about science objectivity were higher than science subjectivity driven by the view that the observations of scientists are generally similar because they are based on empirical facts, and that well-trained scientists are detached from personal values when carrying out investigations. Second, nearly half of the sample disagreed on the impact of subjective methods of scientists to validate scientific knowledge; with the exception that a high percentage of participants agreed on science naturality driven by the acceptance of two different theories about a particular phenomenon. This result may be justified by the study of Christie and Christie (2000) which indicated that the competitiveness between chemical theories is the feature that distinguishes them from other fields of science. Third, nearly half of the sample disagreed on inventing theories and laws because they can be disproved, which is an unexpected result given that several theories in chemistry have been replaced or developed, such as theories about the structure of the atom. However, they agreed that theories and laws are discovered because the idea was there all the time to be discovered. The Islamic theory of knowledge could influence students' views on the knowledge of theories and laws in which knowledge is relative except for what is revealed by one of the two revelations, and this source included a description of a number of scientific phenomena. Unexpectedly, nearly half of the sample disagreed on the existence of a difference between theories and laws despite these concepts being addressed in pre-university chemistry courses. Moreover, most of students had views about the possibility of turning theory into law. This result is consistent with a number of previous studies that showed naive views about the relationships between theories and laws (Agustian, 2020; Alahmad et al., 2019; Alanazi, 2018; Mesci & Schwartz, 2017). Although the objectivity of science was higher in the views of university chemistry students, most students had informed views about the impact of social and cultural values in the direction of scientific inquiry. They also held contradictory views about the nature of scientists' observations and the use of imagination. This can be justified by the structure of beliefs being organised in the form of clusters and groups, which may lead to contradictions or the development of some beliefs over others (Schommer & Dunnell, 1997).

Moreover, since nearly half of the sample held inaccurate views regarding the impact of personal beliefs on scientists' observations, attitudes toward teaching this concept received the least percentage of agreement. This may be explained by the impact of personal beliefs on scientists' observation as being one of the justifications for the relativity of scientific knowledge. According to Hudson, students' learning about the relativity of scientific knowledge may reduce their confidence in science causing them to adopt negative attitudes towards science learning (2014, as cited in Alshamrani, 2021). This is evidenced by the fact that (38.9%) of university chemistry students refuse to teach the relativity of scientific knowledge because it reduces students' acceptance and interest in learning. This result is inconsistent with the study of Alahmad et al. (2019), which showed high trends among university science students on teaching the influence of personal beliefs on scientists' observations.

On the other hand, nearly half of the sample disagreed on the diversity of scientists' methods in scientific research, as well as attitudes toward teaching these methods. This can be attributed to the lack of philosophical courses in study plans that address the nature and history of science, or the poor employment by chemistry teach-

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ers of activities or methods that encourage diverse or new research practices, or stimulate reflection on the diverse methods of scientists. This finding is consistent with Sumranwanich and Yuenyong (2014) which indicated that the majority of graduate students in science education did not agree with the diversity of scientists' methods in research.

The results also revealed the weak contribution of university chemistry courses in developing the views of university chemistry students about NOS, which did not show a significant difference by academic level, except that second-level students had more informed views than fifth-level students; this can be justified by the lack of philosophical courses that address NOS and its history. Several studies have indicated the contribution of including topics in NOS to the development of the concepts of science (Sumranwanich & Yuenyong, 2014; Piliouras et al., 2018). This result is consistent with the study (Agustian, 2020), which indicated that the chemistry laboratory context was insufficient to develop the concepts of NOS among undergraduate chemistry students and recommended integrating NOS into university science curricula. This result is also consistent with the views about NOS among student teachers in Turkey, which did not show any statistically significant difference by the variable of academic level, despite the concepts of NOS and its history being addressed in the final academic levels (Yenice, 2015).

The high standard deviation in most of the research results may highlight the influence of individual context on chemistry students' views about NOS more than being of one scientific discipline, academic level, or university.

Conclusions and Implications

Understanding NOS among university science students is important as it is an essential component of scientific literacy. Moreover, measuring university chemistry students' NOS at varying academic levels contributes to providing feedback on teaching NOS in chemistry courses in pre-university and university education, as well as the key role of specialised and educational teacher preparation programmes in developing views about NOS. Since there are inaccurate Saudi undergraduate chemistry students' views about some concepts of NOS, as well as the students of the final levels not having more informed views than those of the primary levels. It is recommended to support university chemistry curricula with activities that develop the employment of diverse methods in scientific research; it is also recommended to promote reflection on NOS, especially on the various methods used by chemists in scientific research, the difference between theories and laws, and the influence of subjectivity in scientists' practices. Moreover, students' reflection on quantum chemistry theories, stereochemistry and isomers can assist their understanding of these concepts clearly.

In light of the statistically significant differences between the views of chemistry students according to the different universities, it is proposed that the factors affecting the weakness of views about NOS among female students of Imam Muhammad bin Saud University be a focus for future research. Moreover, due to the presence of research evidence on the positive impact of having philosophical perceptions about science among chemistry students on the quality of their learning, the current research suggests studying the relationship between the views of chemistry students about NOS in this study with the results of academic achievement of chemistry students in each of those universities. However, since the high standard deviation in most of the study results, it can be concluded that the individual context on learners' views about NOS has more effect than the effect of their being in one scientific discipline, one study level, or one university. Although the research sample was taken from eight universities within different regions across the Kingdom of Saudi Arabia, it was limited to females, which may, in turn, limit the ability to generalise the results. Therefore, it is recommended to identify and compare the views of NOS among male chemistry students in universities.

Declaration of Interest

The authors declare no competing interest.

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