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Toward Understanding Science as a Whole

Investigating Preservice Teachers' Perceptions About Nature of Science in the United Arab Emirates

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Abstract
Nature of science (NOS) is a global conception of the infrastructure of science and, therefore, forms the foundation for teaching and learning science, especially for preservice teachers who are expected to have the proper understanding of NOS to thoughtfully emphasize NOS within their instruction to students. However, studies investigating UAE science preservice teachers' views of NOS through the macro-lens of the Reconceptualized Family Resemblance Approach to Nature of Science (RFN) are limited. This study, therefore, aims to determine the current state of UAE preservice teachers' ($N = 130$) understanding of the NOS and NOS instruction. Results obtained from the RFN 70-item questionnaire demonstrate that teachers were mostly informed about issues pertaining to the social-institutional aspects compared to aspects related to the cognitive-epistemic nature of science. Although teachers appeared to hold informed perceptions on certain aspects of NOS across the RFN scales and subscales, they had mixed views, as well as misconceptions on other particular aspects of NOS (i.e., the role of bias, gender, and politics on scientific knowledge, the existence of a universal scientific method, and the distinction between laws and theories). Practical and pedagogical implications for teaching and an agenda for further research are discussed.

1 Introduction

In the pursuit of preparing scientifically literate citizens, science teaching needs to be relevant, responsive, and situated within the larger context of the world. More explicitly, it has to address the multidimensional and cross-disciplinary nature of science while making connections to the epistemology, history, sociology, and philosophy of science, as well as to the society, industry, and technology, along with considerations of the surrounding ethical discussions (Abell & Smith, 1994; Sahin & Deniz, 2016). This is, indeed, the essence of the nature of science (NOS) which describes how science functions through multiple

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lenses in a way that accurately portrays the reality of science. Matthews (1998) nicely articulated this focus indicating that the hope of science education should be to enhance society, the quality of culture, and public life, by enabling students to appreciate the nature of science, internalize the scientific spirit, and develop a scientific frame of mind that can inform different aspects of their lives.

NOS is a global concept that acts as a foundation for teaching and learning science (Hammerich, 1998); or as expressed by Bohm and Peat (1987), it is the infrastructure of scientific knowledge. It has been considered a crucial component of scientific literacy and a major goal for the science curriculum for several decades, both locally and worldwide (Abd-El-Khalick & Lederman, 2000; Abell & Lederman, 2007; Aflalo, 2018; Cakmakci, 2017; Carter & Wiles, 2017; Hodson, 2009; Kaya & Erduran, 2016; Kimball, 1967; Koerber et al., 2015; Millar & Osborne, 1998). This was evident in key science education documents (e.g., AAAS 1990, 1993; NRC, 1996, 2013) which stressed the inclusion of NOS in science education from K-12, with implications on science curriculum, assessment, and teacher education (Hanuscin et al., 2010; Kaya et al., 2017; Lederman & Lederman, 2019).

Specifically, many endeavors were undertaken by the United Arab Emirates (UAE) science education system to support the authentic understanding and effective delivery of NOS content, which is considered to be an essential component in science education (Al-Naqbi, 2010). For instance, the new national curricula in the Emirati education system have been designed in line with the Next Generation Science Standards (NGSS) which emphasize elements of NOS (Saleh, 2018; Shaker & Saleh, 2021). The curricula are directed toward students' acquisition of the skills of experimentation, investigation, observation, and drawing conclusions while providing multiple opportunities for practical experience of these in the real world. In addition, attempts have been made in the updated curriculum for creating an integrative approach to science learning across all grade levels as the science curriculum in many cases, establishes connections between science and other learned subjects and disciplines (e.g., Computer Science, Creative design and Innovation, Business Management, Mathematics, Social Studies, and National Education, Moral Education) (The UAE Ministry of Education portal, 2022).

Despite the inclusion of NOS in science curriculum as a result of the recent educational reforms in the UAE and worldwide, research into perceptions of NOS indicated that teachers lack a sophisticated understanding and purposeful teaching of the NOS, which in turn, can potentially impact their instructional decisions and their students' understanding (Bilican et al., 2015; Karaman, 2018; Lederman, 2007; Lederman & Lederman, 2019). These findings are sobering because an incomplete or improper understanding of NOS may negatively impact the success of NOS instruction. This means that science teachers may mistakenly communicate narrow and erroneous ideas, as well as misconceptions about NOS to their students (Abd-El-Khalick & Lederman, 2000; Celik & Bayrakceken, 2012; Kaya, 2012). This is potentially problematic as it may impede students' ability to construct more complex understandings of science as they progress through their studies.

Accordingly, teachers' knowledge of NOS cannot be overlooked nor considered peripheral to their teaching of science since they may significantly frame, positively or negatively, their students' overall scientific understanding and awareness (Forawi, 2014; Gheith & Aljaberi, 2017). Critically, there is evidence showing that prospective school science teachers, although being interested in science, may be only superficially aware of the cognitive, epistemic, and social-institutional aspects of science, and may have no clear idea how science operates (Lederman & Lederman, 2019; Miller et al., 2010), mainly because their beliefs about NOS remained unchallenged during the teacher education programs (Akerson et al., 2008). Some researchers even argue that preservice teacher education programs often overly emphasize on the scientific content knowledge without taking into consideration other aspects, such as the epistemological and sociological factors of science (Saleh & Khine, 2014). Thereby, a greater push in the most current directions in the NOS literature has emphasized the importance of diagnosing and altering epistemologies and beliefs about of NOS for both prospective and practicing science teachers (Kaya et al., 2019; Tala & Vesterinen, 2015; Wilcox & Lake, 2018).

Various tools have been developed and used, both quantitatively and qualitatively, to assess, challenge, and broaden the fundamental conceptions of NOS such as questionnaires, interviews, classroom observations, small group discussions, and writing tasks. A relatively recent theoretical approach to NOS in literature is the Reconceptualized Family Resemblance Approach to Nature of Science (RFN) (Erduran & Dagher, 2014). The framework presents a coherent and holistic account of NOS while addressing the interplay between various aspects of NOS such as the cognitive-epistemic (e.g., scientific aims and values, scientific practices, methods, and knowledge) and social-institutional aspects (e.g., social ethos, professional activities, certification, political power structures, and financial systems). It is unique in its comprehensiveness and dynamic nature mainly because it takes into account these multiple factors that interact with science as both an enterprise and a practice, with a specific focus on their pedagogical applications in practice (Erduran & Kaya, 2019; Lederman & Lederman, 2019; McDonald, 2017; Yeh et al., 2019). That is to say, teaching science through the macro-lens of RFN is particularly important for science education contexts as it broadens avenues of NOS teaching while addressing NOS elements in instruction, learning outcomes, curriculum development, and assessment (Dagher & Erduran, 2016).

It is often considered to be challenging to teach science in the early years of schooling and, in fact, this topic has not been sufficiently addressed in the literature (Wilcox & Lake, 2018). Consequently, examining NOS perceptions of university students preparing to become early years and elementary science teachers is of utmost importance as they are expected to hold proper understanding of NOS and motivation to thoughtfully teach and emphasize NOS within their instruction to young students (Chen, 2006; Kaya, 2012). This study, therefore, invited UAE preservice science education teachers in the early years and elementary stages to determine the current state of their understanding of the NOS through RFN (Erduran & Dagher, 2014) which has been studied empirically in pre-service science education settings (Erduran et al., 2018). This is a fruitful area to explore as locally, to date, no study has been undertaken with this focus. A second aim was to assess differences in NOS perceptions concerning their demographics, namely, the NOS training and the year of study. The study is framed by the following research questions:

1. What are the perceptions of UAE preservice teachers toward NOS?
2. How do the teachers' perceptions of NOS significantly differ across the RFN scales?
3. How do teachers' perceptions of NOS differ in relation to their year of study and whether they have been trained in NOS?

Although the study was conducted within the context of UAE, it theoretically contributes to the literature that promotes a holistic approach to NOS teaching and learning through the RFN framework (e.g., Akgun & Kaya, 2020; Erduran & Dagher, 2014; Erduran et al., 2019). Building on the RFN, the findings of the present study are expected to add an alternative perspective to the understanding of the NOS that is based on broader views and ideas instead of the traditional aspects described in previous studies such as tentativeness of scientific knowledge and its empirical nature. Additionally, given that teacher education programs are in the best position to ensure well-planned NOS content and high-quality NOS instructional strategies (McComas, 1998), the current findings can be of interest to coordinators and curriculum developers of teacher preparation programs at universities.

2 Theoretical Framework and Literature Review

2.1 Teacher Preparation and Understanding of NOS

Teacher preparation plays an important role in any education advancement plan. Specifically, institutions that provide teacher preparation programs influence future teachers' understanding of science and NOS. Research shows that teacher preparation programs that provide access to high-quality teaching of NOS help learners develop a conceptual understanding of the multimodal approach to NOS learning in parallel with the science academic content (Nur & Fitnat, 2015; Torres et al., 2015; Wilcox & Lake, 2018). By implication, preservice teachers will be able then to develop views that reflect an extensive and realistic depiction of NOS, enabling them to include more teaching activities that target NOS explicitly in their practices (Akerson & Volrich, 2006). As such, teacher preparation programs at universities are a major factor in developing conceptions and equipping future teachers with knowledge and skills that help them implement an understanding of NOS in different domains (Yilmaz-Tuzun, 2008). Although courses in some of these programs might focus on scientific methods and aim at preparing future teachers for teaching science content, they are not necessarily linked to their interpretation of NOS concepts into their expected practices.

Overall, the majority of relevant existing studies aimed at describing participants' views of NOS in terms of the level of understanding of its aspects and looked at how adequate these views are in general (Akerson et al., 2010; Kaya, 2012), whereas other studies have investigated the nature of these views in terms of its theoretical perspective (Gheith and Aljaberi, 2017). Some studies also targeted exploring the views of preservice teachers within the university context by measuring the impact of a NOS-related course on the views (Celik & Bayrakceken, 2012; Krell et al., 2015; Mesci & Schwartz, 2017). It was generally concluded from these studies that the courses had a positive impact on the participants' views about NOS by either building an accurate knowledge base of its elements or deepening their understanding of accumulated knowledge of NOS, with differences in the levels of understanding of certain aspects, such as the social and cultural factors.

Relevant to this study, Akerson et al. (2010) explored NOS perceptions of preservice teachers in the early years and elementary stages and found that teachers had acceptable views of the NOS, but were not necessarily reflected in their implementation of teaching science activities. A similar sample from a public university in Turkey participated in Kaya's (2012) study to assess their views of NOS. Although teachers belonging to Elementary Education majors were exposed to more science-related content and explicit NOS instruction in their courses, their views were not different from the ones majoring in early childhood, as teachers from both groups were found to possess several misconceptions regarding NOS. That is to say, the depth of understanding of NOS was found to be irrelevant to the number of science-related courses that preservice teachers have enrolled in. This finding therefore may have an important implication on the content and structure of science education courses when attempting to secure more effective preparation of teachers in the area of NOS.

Similarly, Gheith and AlJaberi's (2017) study targeted the perceptions of Jordanian preservice teachers regarding NOS. The 93 students majoring in Elementary School Teacher and KG teacher provided responses to the researcher-developed questionnaire. The findings implied that participants' views about NOS reflected a constructivist perspective, and no significant differences were found between participants according to major or year of study. In addition, a number of studies aimed at assessing the impact of taking specific NOS courses on the views of preservice teachers about NOS (e.g., Celik & Bayrakceken, 2012; Krell et al., 2015; Mesci & Schwartz, 2017). Celik and Bayrakceken (2012) for example studied the impact of a course that included NOS content on the views of 36 participants who applied for teacher certification. The researchers have found that participants had a low understanding of NOS concepts as a whole prior to attending the course, and their views were specifically less informed in the elements of laws and theories, social, and cultural factors. Their overall views have significantly changed after taking the course, except for the social and cultural factors which were not largely affected.

2.2 Reconceptualized Family Resemblance Approach to Nature of Science and Preservice Teachers' Understanding of NOS

The Reconceptualized Family Resemblance Approach to Nature of Science (RFN) was developed and expanded from the Family Resemblance Approach (FRA), a concept that was first introduced by Wittgenstein and then adapted by Irzik and Nola (2014). It originally included the elements of aims/values, methodologies/methodological rules, scientific activities, and products of science to describe and explain science. A prominent feature of the model is its applicability to different branches of science. That is, utilizing each domain of FRA in the description and analysis of science as a whole while successfully approaching all sciences such as biology and chemistry standing from the lenses of FRA (Kaya et al., 2019). This exceptional feature comes from viewing those different sciences as if they belong to a family where each member is unique in its own specifications, and yet share common features, and thus came the choice of the term "Family" in the name of the Approach (Kaya & Erduran, 2016). Irzik and Nola (2014) broadened the FRA scope by the inclusion of social-institutional aspects of science.

After that, Erduran and Dagher (2014) introduced the term RFN that extended the interpretation of NOS to magnify how science is influenced by other factors. Specifically, they expanded the social-institutional categories to cover political, financial dynamics, social hierarchies, and organizational aspects as these factors greatly impact how science operates. Moreover, the addition of educational applications was a step that remarkably increased the value of the framework in educational contexts (Erduran & Kaya, 2019). In this sense, the RFN is believed to reflect the interrelated dynamics of NOS various dimensions (e.g., cognitive-epistemic and social-institutional system), as well as promotes application of these to the pedagogical, instructional, curricular, and assessment issues in science education (Caramaschi et al., 2021; Cullinane & Erduran, 2022; Kaya & Erduran, 2016; Yeh et al., 2019). Even though the dimensions of the RFN and the elements subsumed within are characteristically defined (Erduran et al., 2018), the malleability of the framework allows newly developed or discovered aspects to fit into it. The RFN framework is being increasingly advocated by emerging literature on NOS because it presents NOS as the totality of the science learning journey while drawing on most prominent international research, theories, and practices, along with data gathered from a number of empirical studies in different contexts (e.g., Akgun & Kaya, 2020; Azninda & Sunarti, 2021; Bou-Jaoude et al., 2017; Kaya et al., 2019).

Multiple instances were reported in literature in which the RFN was used to examine preservice science teachers views on NOS. For instance, Kaya et al. (2019) examined preservice teachers views on NOS ($n = 15$) in the senior year before and after attending a course that included NOS content. The results found that all the domains of RFN including the social-institutional dimensions became visibly more understood as a consequence of taking the course, whereas the domain of scientific practices did not score a change that was significantly different. Also, the differences between preservice teachers' views of NOS according to university majors were explored in Azninda and Sunarti's (2021) study by using RFN questionnaires and interviews with participants from science education, language education and social education majors ($n = 25$). Results showed that the major of the preservice teachers was not linked to the difference in views. The interviews, however, revealed that participants from the non-science majors expressed views that were distinguished from the views of participants from other majors, specifically for the social domain, whereas preservice teachers from the science major however focused on scientific methods and practices. These findings were attributed to the difference in their preparation as the two groups take courses which overly tend to emphasize either scientific content or social sciences' content.

In another attempt, Akgun and Kaya's (2020) study investigated the views of university students ($n = 15$) from different science and non-science majors (such as majors of science education, preschool education, and foreign language education). Interestingly, results found that the participants from the non-science major were the ones who showed more adequate views of NOS in RFN dimensions, specifically for the cognitive-epistemological dimensions including laws and theories, scientific methods, and scientific knowledge, and the social-institutional dimensions. However, participants from science majors were more informed about the dimensions of scientific knowledge and scientific practices.

Taken collectively, the aforementioned reviewed studies are minimal and somehow similar in their scope due to the fact that the reconceptualized framework is relatively new. While a few studies adopted qualitative methods solely (Saribas et al., 2019), the majority of studies triangulated them with the RFN questionnaire (Akgun & Kaya, 2020; Azninda & Sunarti, 2021; Kaya et al., 2019). Findings generated from these studies shed light on the significance of the teacher education and preparation programs in preparing highly-qualified science teachers who are capable of reinforcing learners' understanding of the variety of concepts that NOS entails. They also draw attention to how teachers' understanding of NOS can be linked to their previous experiences and engagement in meaningful NOS learning.

3 Method

Methodologically, the present study employed a cross-sectional survey method to provide the opportunity to collect data from a large number of participants to get an overview of their perceptions, as well as to assess similarities and differences across their responses (Gay et al., 2009). This study is specifically introduced as part of a funded research project that focuses on the early years' science education in the UAE with the purposes of exploring teachers' views of NOS and implementing a professional development program that adopts RFN as a framework. The research ethics approval was obtained from the Social Science and Humanities Ethics Committee at the authors' institution.

3.1 Participants

All preservice teachers studying in the Early Childhood and Elementary Education majors at the College of Education from one public university in the UAE were invited to participate in the current study. The sample consisted of 130 preservice teachers who responded to the questionnaire. The majority of participants were within the age range of 17–26 years old and from the UAE (96%). 78% of the participating teachers specialized in teaching at the kindergarten level, whereas 36% remaining students were candidates to teach at the elementary level grades (grades 1–5). Table 1 shows the demographic details of the participants.

Table 1 Demographic characteristics of the study participants

Demographics of the study sample ($N=130$)		
Characteristics	Frequency (*n*)	Percent (%)
Age		
17–21 years	78	60
22–26 years	51	39.2
27–31 years	1	0.8
Above	0	0
Nationality		
UAE	125	96.2
Oman	3	2.3
Others (Syria and Jordan)	2	1.6
Current year of study		
Year 1	12	9.2
Year 2	41	31.5
Year 3	41	31.0
Year 4 (Last year)	36	27.7
Specialized grade Level		
Pre-KG	17	13.1
KG 1	22	16.9
KG 2	2	1.5
Both KG 1 and KG 2	61	46.9
Elementary Level Early Grades (Grades 1–3)	14	10.8
Elementary Level Upper Grades (Grades 4–5)	14	10.8%
Received course or training on teaching and learning of "Nature of Science"		
Yes	30	23.1
No	100	76.9

3.2 Context of the Study

Undergraduate students majoring in Early Childhood and Special Education majors are expected to satisfy their graduation requirements by taking two courses (6 credits) from the Natural World cluster including one course in the area of sustainability and another course from the university natural science courses list, which include “Introduction to Fish and Animal Sciences,” “Natural Resources,” “Biology and its Modern Applications,” “Chemistry in the Modern World,” “Principles of Food Science Nutrition,” “Planet Earth,” “Astronomy,” “Physical Fitness and Wellness,” and “Conceptual Physics.” These courses aim to help teachers-to-be acquire the necessary knowledge in the area of natural science and scientific inquiry. In addition to that, Early Childhood Education majors are required to take three compulsory courses in the area of science to suffice the professional (“Child Health and Care” and “Science Education for Young Children”) and major (“Natural Science 1”) requirements. For instance, in the “Science Education for Young Children” course, preservice teachers consider more carefully the teaching of science in early childhood while embracing the different cultural and social backgrounds. They utilize the early childhood education lab for micro-teaching of scientific activities to recognize how these activities will look and feel like for children, such as using skills of inquiry to explore basic phenomena and materials, demonstrating methods of science, and focusing on an array of hypotheses. Additionally, they learn how to prepare lesson plans for simple science investigation activities in the early childhood teaching and learning environments while addressing the interplay among basic scientific concepts and doing science (processes and skills of science such as describing, comparing, and classifying objects; raising questions; making and recording observations using words, drawings, or charts; developing hypothesis and explanations, and working collaboratively with others to present results and share ideas).

3.3 Instrument

The instrument used to investigate preservice teachers’ perceptions was the Reconceptualized Family Resemblance Approach to Nature of Science Questionnaire (RFNQ) developed by Kaya et al. (2019) (Appendix 1). The original questionnaire that was developed in English was used because English is the medium of instruction at the university, and therefore, was appropriate for the target participant group. The questionnaire includes 70 items that are presented in a 5-point Likert scale (“strongly disagree,” “disagree,” “not sure,” “agree,” “strongly agree”) where participants can indicate their level of agreement with each statement. The questionnaire is composed of three main scales: cognitive-epistemic system, social-institutional system, and educational applications. The cognitive-epistemic system scale encompasses four subscales, namely, aims and values, scientific practices, scientific methods, and scientific knowledge, as shown in Table 2.

3.4 Data Collection and Analysis

An online version of the questionnaire was developed and distributed via an email invitation to the target participants asking them to take part in the study. A second reminder email was sent again one week after. Statistical analysis was performed to analyze the quantitative data using SPSS. At first, the negative items under each scale were reverse-coded prior to the analysis. The data found to be normally distributed throughout the study population. Descriptive statistics in terms of mean (*M*) and standard deviation (*SD*) were

Table 2 Scales, subscales, and items distribution of RFN-Questionnaire

Major scales	Subscales	Number of items	Positive items	Negative items
Cognitive-epistemic system encompassing	*Aims and values*	7	2, 20, 40, 51, 69	46, 56
	Scientific practices	13	4, 5, 15, 19, 23, 33, 38, 57,61, 63	26, 52, 64
	Scientific methods	9	11, 22, 24, 28	8, 25, 37, 49, 60
	Scientific knowledge	9	10, 30, 44, 50, 54	3, 16, 43, 66
Social-institutional system		16	7, 9, 14, 32, 34, 41, 45, 48, 53, 58, 67, 70	13, 18, 36, 39
Educational applications		16	1, 6, 12, 17, 21, 27, 29, 31, 42, 55, 59, 62, 65	35, 47, 68

calculated to gauge the overall tendency of the responses on RFN questionnaire scales, sub-scales, and for each item. Furthermore, detailed descriptive results in terms of frequency and percentages were computed for responses distribution across individual items on the 5-point Likert scale options to assist in identifying the level to which the sample group agrees or disagrees with each of the individual items. Also, the Pearson's r correlations between RFNQ scales were tested using a significance level of 0.01. Cronbach's α of the whole questionnaire was (0.89) and yielded a coefficient greater than 0.70 per scale which is considered acceptable for internal consistency reliability (Nunnally, 1978). Paired samples t-tests at p-level < 0.05 were performed to look for differences in the pre-service teacher's perceptions of NOS between the RFNQ scales (cognitive-epistemic and social-institutional, cognitive-epistemic and educational application, and educational application and social-institutional). Last, a one-way analysis of variance test was performed to determine differences in NOS perceptions across the three scales based on the participants' demographics (receiving training on NOS and year of study).

4 Results

The first question aimed at assessing the perceptions of preservice teachers toward different aspects of NOS. Table 3 presents mean and *SD* scores on RFN questionnaire scales and subscales. Overall, the average summary score for the whole questionnaire items was $M = 3.46$ ($SD = 0.29$). On the scale level, the mean score for the social-institutional scale ($M = 3.60$, $SD = 0.39$) was slightly higher than that for the educational applications scale ($M = 3.55$, $SD = 0.38$), whereas the least mean score occurred for the cognitive-epistemic scale ($M = 3.37$, $SD = 0.25$). At the subscale level, the "scientific practices" received the highest mean score ($M = 3.55$, $SD = 0.38$), and mean values were relatively close for both "aims and values" ($M = 3.38$) and "scientific knowledge" ($M = 3.33$). The "scientific methods" subscale, on the other hand, obtained the least mean score ($M = 3.13$, $SD = 0.28$).

The second research question aimed to further determine if preservice teachers' perceptions of NOS significantly differ across the RFN scales. To answer this question, paired samples t-tests at p-level < 0.05 were performed to look for differences, as shown in Table 4. Scores were significantly different between the cognitive-epistemic scale and social-institutional scale ($t = -10.91$, df $= 129$, $p < 0.001$), as well as between the cognitive-epistemic and the educational applications ($t = -8.68$, df $= 129$, $p < 0.001$). In both

Table 3 Mean and SD scores for RFN questionnaire scales and subscales

Scales/Subscales	Range	Minimum	Maximum	*M*	SD	Variance	Items no
Whole questionnaire	1.29	2.91	4.20	3.46	0.29	0.084	70
Scale 1: Cognitive-epistemic system	1.24	2.84	4.08	3.37	0.25	0.64	38
Aims and values	2.43	2.00	4.43	3.38	0.41	0.171	7
Scientific practices	2.00	2.77	4.77	3.55	0.38	0.144	13
Scientific methods	1.56	2.33	3.89	3.13	0.28	0.080	9
Scientific knowledge	1.44	2.67	4.11	3.33	0.29	0.87	9
Scale 2: Social-institutional system	2.00	2.75	4.75	3.60	0.39	0.156	16
Scale 3: Educational applications	2.00	2.38	4.38	3.55	0.38	0.141	16

Responses are rated on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree)

Table 4 Results for paired samples *t*-tests for perceptions of NOS between the main scales

	Paired differences					*t*	df	Sig. (2-tailed)
	Mean	Std. deviation	Std. error mean	95% confidence interval				
				Lower	Upper			
Cognitive-epistemic and social-institutional	−0.23	0.24	0.02	−0.27	−0.19	−10.91	129	0.000
Cognitive-epistemic and educational application	−0.19	0.25	0.02	−0.23	−0.14	−8.68	129	0.000
Educational application and social-institutional	−0.05	0.25	0.02	−0.09	−0.00	−2.04	129	0.044

cases, mean scores for the cognitive-epistemic scale ($M=3.37$, $SD=0.25$) were lower than that for the social-institutional scale ($M=3.60$, $SD=3.39$) and the educational applications scale ($M=3.56$, $SD=0.38$). However, scores were not significantly different between the educational applications and social-institutional scales ($M=-0.05$, $SD=0.25$), $t(129)=-2.04$, $p=0.044$.

Figures 1 and 2 below illustrate mean scores and percentages of responses distribution on the 5-point Likert scale for items of the first subscale that concerns preservice teachers' perceptions about the aims and values of science (see data Table 7 in Appendix B). As can be seen in the figures, the highest mean score across all the items occurred for item 40 "scientists should change their minds when they realize that their ideas are not supported by evidence" ($M=3.69$). The "need to consider teaching scientific values as part of the science curriculum" (item 51) also received a high rating ($M=3.69$), as well as "the effect of scientific aims and values on choice of methods" ($M=3.68$). However, mixed views were seen for item 2 (26% disagreed, 42% were not sure, and 32% agreed). 52.3% of the participants seemed to be uncertain about whether "scientific facts are not affected by bias and prejudices" (13% agreed and 34.6% disagreed), yielding the lowest mean score across items for this subscale ($M=2.79$).

In the second subscale relating to preservice teachers' perceptions about scientific practices, as shown in Figs. 3 and 4 (see data Table 8 in Appendix B), item (23) indicating "the use of observations by all branches of science" received the highest mean score ($M=3.92$) across all the items for this subscale. Likewise, the majority of the teachers (72%) agreed with item (19) indicating the importance of "using models to understand phenomena" ($M=3.9$), and a similar percentage of them (71%) also agreed with item (63) indicating the importance of "using models to explain and predict complex phenomena" ($M=3.90$). Around 75% of the teachers considered "data analysis and interpretation as scientific practices" ($M=3.89$), and around 70% agreed that "scientists review and assess each other's work" ($M=3.82$) against "standards specified for evaluating the quality of scientific work"

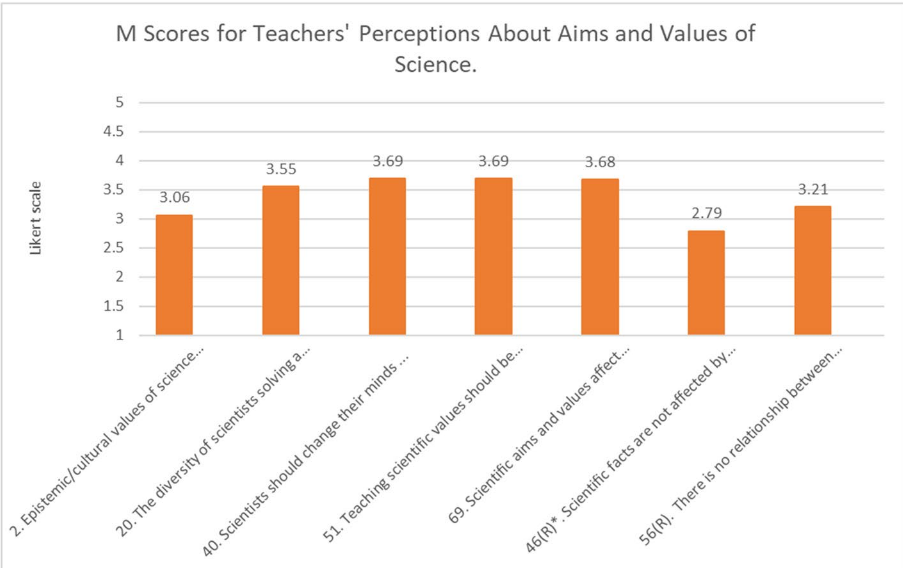


Fig. 1 *M* scores for perceptions about aims and values of science

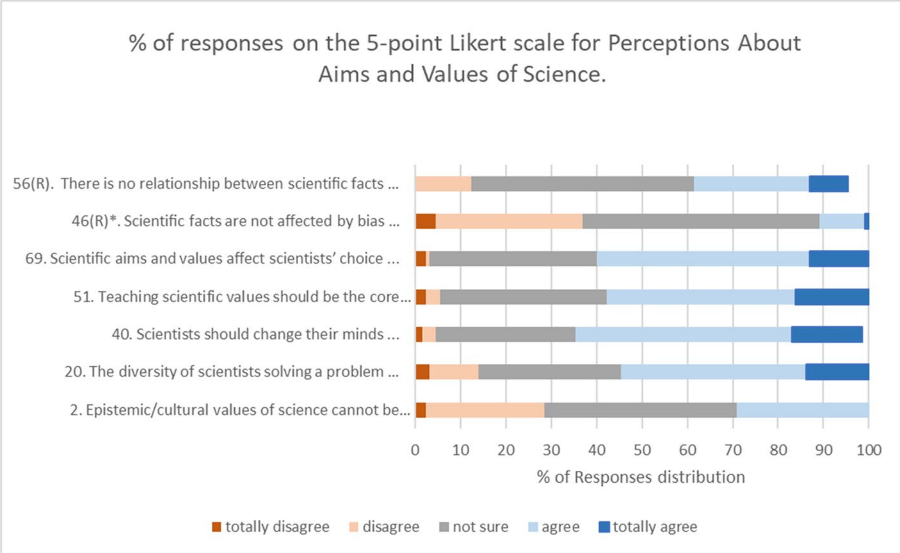


Fig. 2 % of responses on the 5-point Likert scale for perceptions about aims and values of science

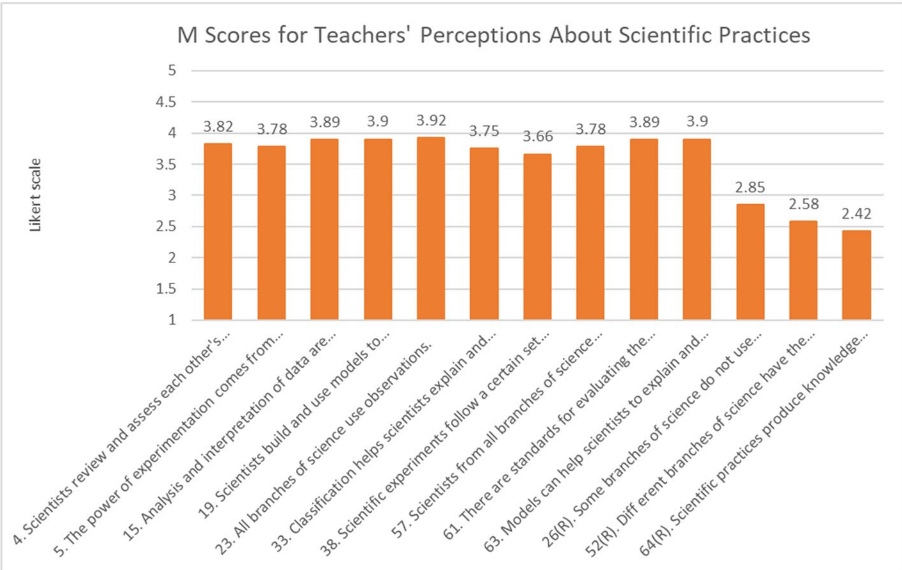


Fig. 3 *M* scores for perceptions about scientific practices

($M = 3.89$). However, teachers believed less that "scientific experiments follow a certain set of procedures" ($M = 3.66$, 59% either strongly agreed or agreed).

Figures 5 and 6 show results for items belonging to the third subscale concerning preservice teachers' perceptions of scientific methods (see data Table 9 in Appendix B). As can be seen, the "diversity of methods for science work" item was considered highly important

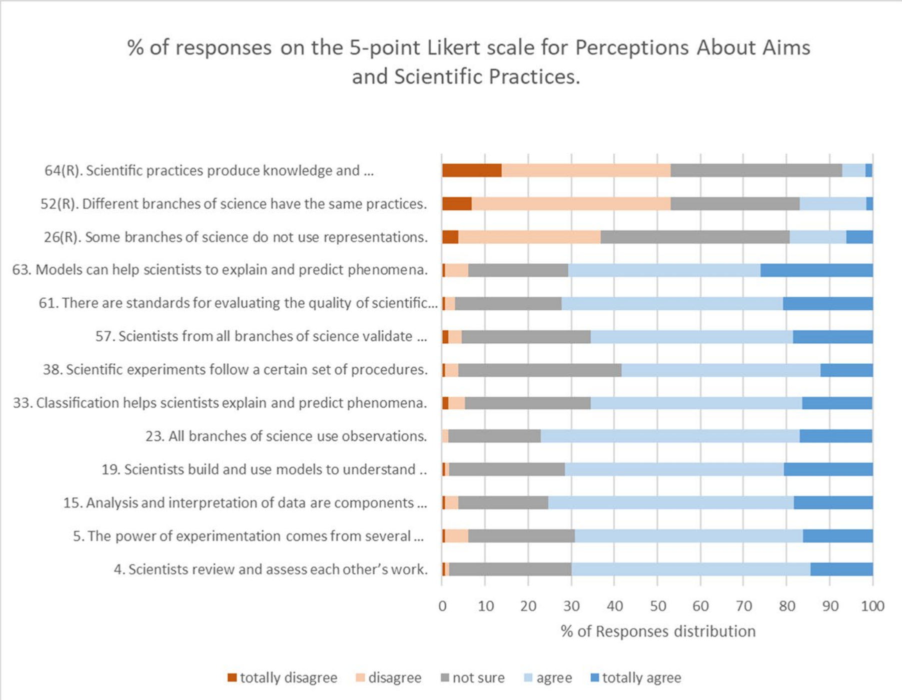


Fig. 4 % of responses on the 5-point Likert scale for perceptions about scientific practices

by the majority of the respondents as seen for items 24 and 28 ($M = 3.9$). Although 57% of the teachers agreed that "each branch of science has a different nature" ($M = 3.85$), their responses varied toward "the existence of standard approach for doing science across scientists and different science disciplines" (items 22, 37, and 8). There appeared to be no clear position on whether "all hypothesis testing is manipulative" (item 25) as responses were relatively close for agreeing (23%), not sure (45%), and disagreeing responses (32%).

Results in Figs. 7 and 8 relating to the fourth subscale "perceptions about scientific knowledge" (see data Table 10 in Appendix B) show that the highest mean score occurred for item 30 "scientific knowledge consists of a coherent set of ideas" ($M = 3.93$). Respondents also greatly acknowledged "the collective contribution of theories, laws, and models in the production of scientific knowledge" ($M = 3.83$, 67% agreed) and that "scientific progress occurs when ideas are evaluated and revised" ($M = 3.86$, 71% agreed). Although 68% of the teachers agreed that "there are different kinds of theories" ($M = 3.75$), only 5% agreed with item (66) "laws are more verifiable scientific knowledge than theories" (41% were not sure and 54% disagreed). Last, around half of the sampled teachers (51%) agreed that "scientific knowledge does not change" (33% were not sure and 16% disagreed).

The next figures (Figs. 9 and 10) present results of preservice teachers' perceptions about social- institutional aspects of science (see data Table 11 in Appendix B). 83% of the participants affirmed "the need for scientists to respect the environment" yielding the highest mean score ($M = 4.22$) across all the items for this category. High mean scores also occurred for items emphasizing various forms of social interactions and activities among scientists such as "participation in conferences for sharing research work" ($M = 3.77$),

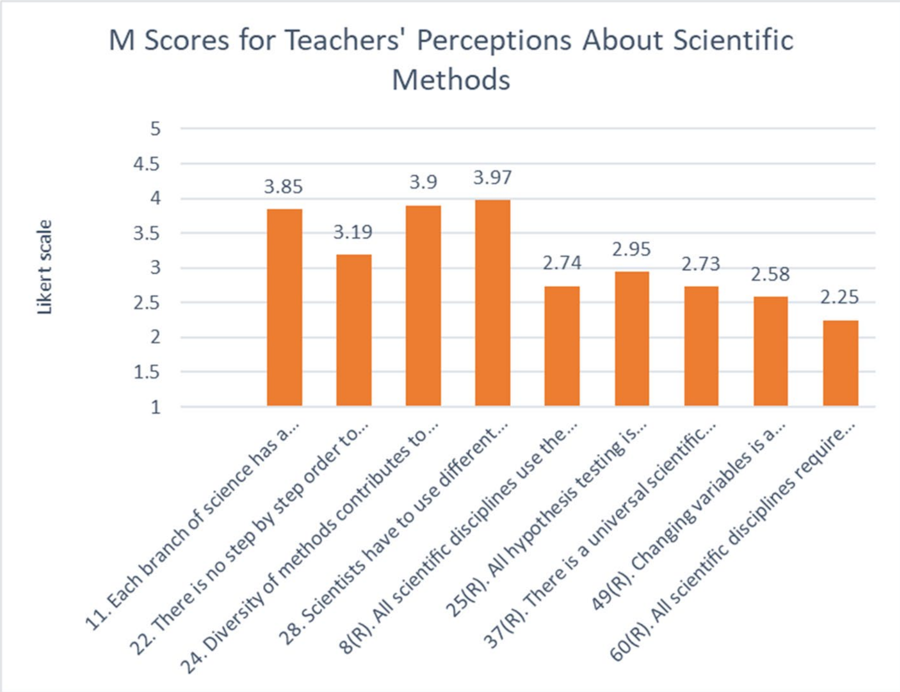


Fig. 5 *M* scores for perceptions about scientific methods

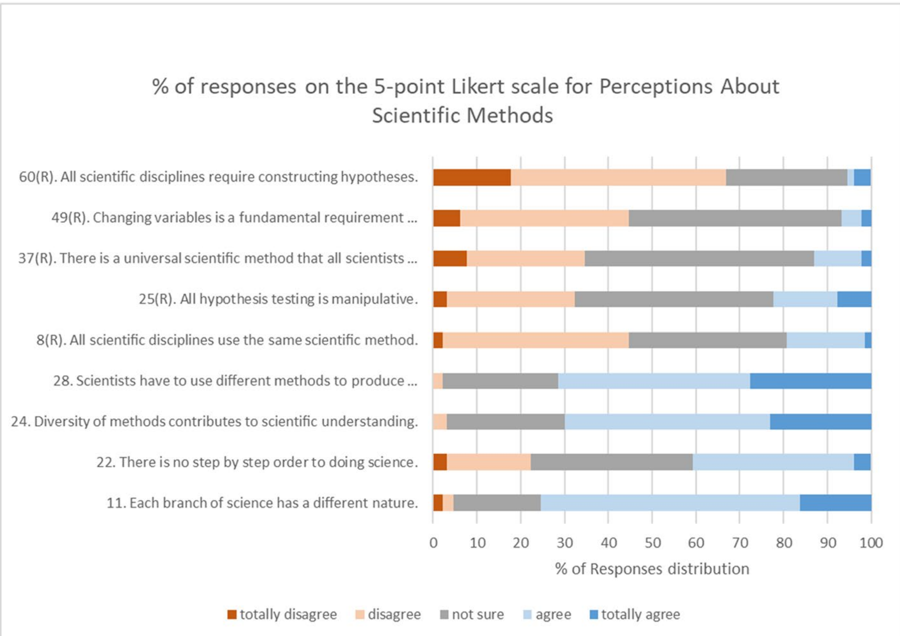


Fig. 6 % of responses on the 5-point Likert scale for perceptions about scientific methods

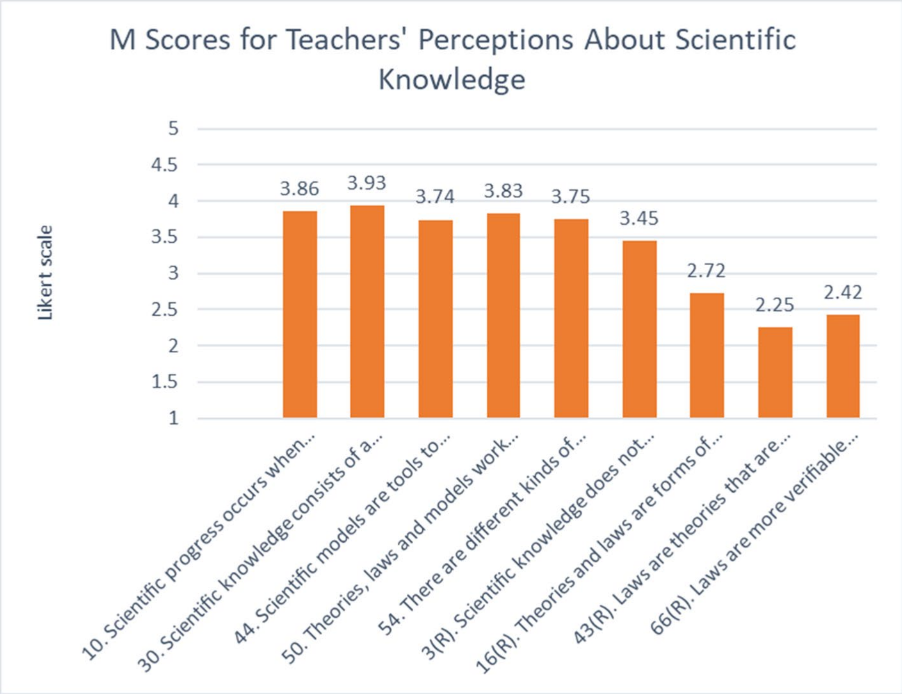


Fig. 7 *M* scores for perceptions about scientific knowledge

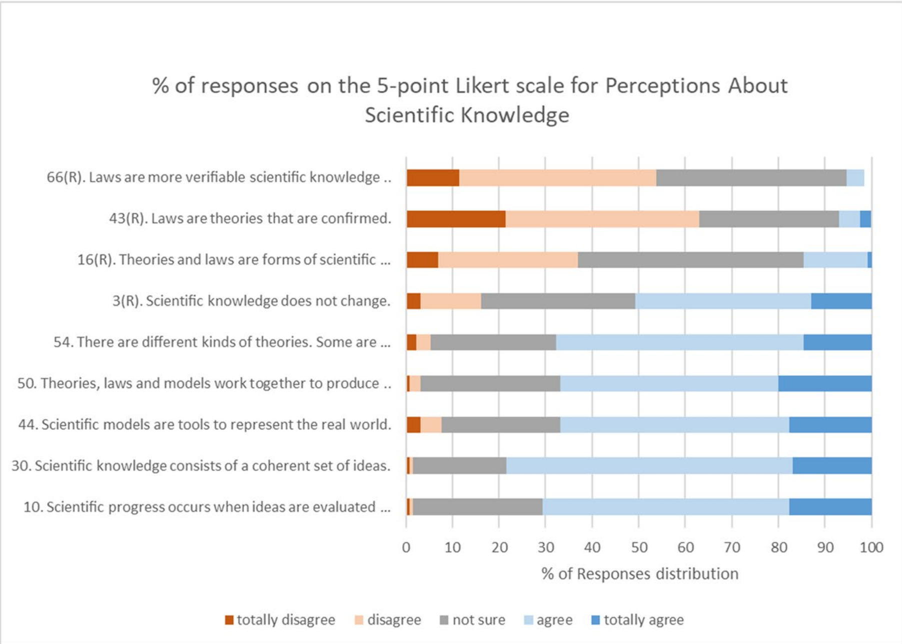


Fig. 8 % of responses on the 5-point Likert scale for perceptions about scientific knowledge

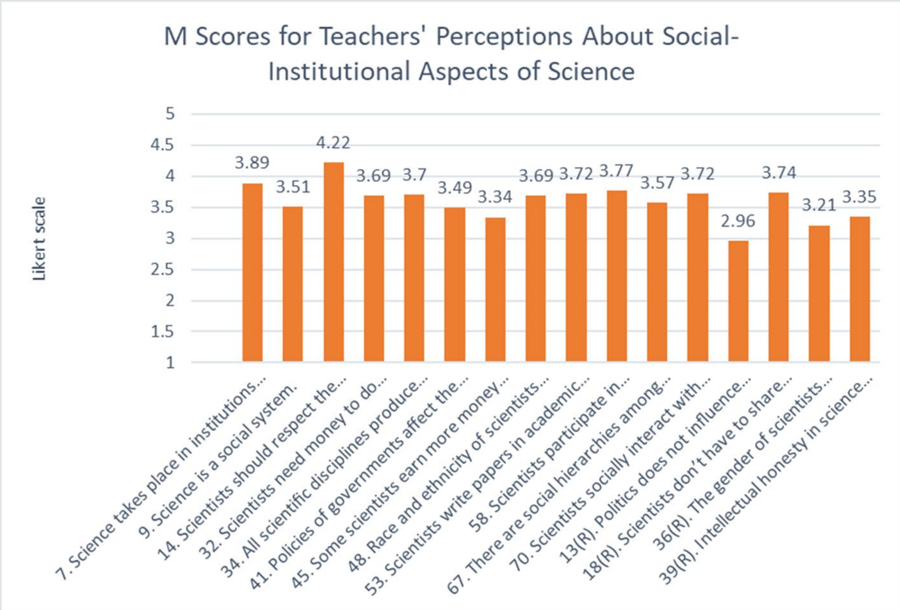


Fig. 9 *M* scores for perceptions about social- institutional aspects of science

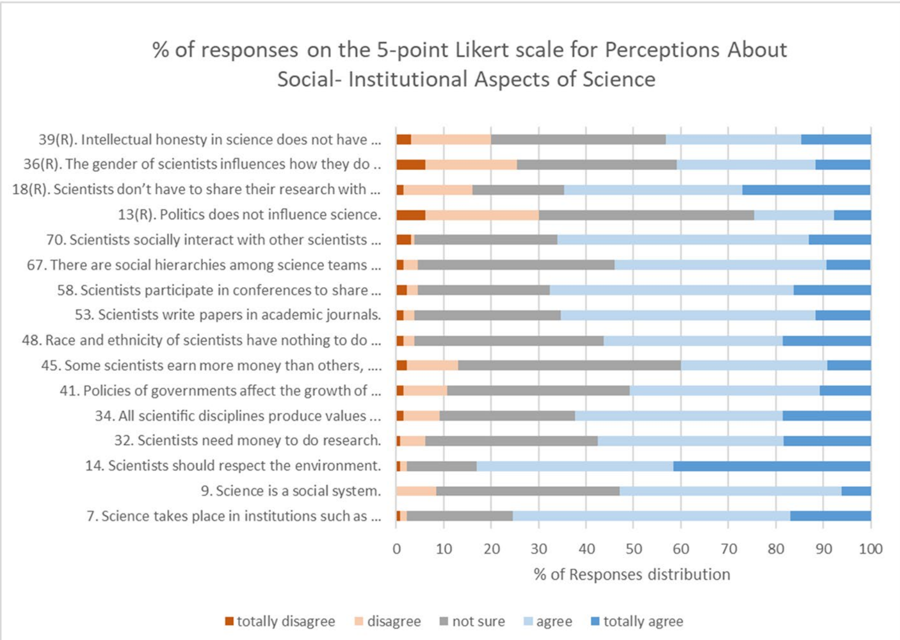


Fig. 10 % of responses on the 5-point Likert scale for perceptions about social-institutional aspects of science

"interacting with other scientists while doing research" ($M=3.72$,), and "writing papers in academic journals ($M=3.72$). Yet, 65% of the teachers agreed that "scientists do not have to share their research with society" ($M=3.74$). Multiple responses were witnessed for item (13) indicating that "politics does not influence science" (25% agreed, 45% were not sure, and 30% disagreed) with the least mean score (2.96). Last, only 41% believed in "the impact that gender may have on science doing" ($M=3.21$), and that "race and ethnicity of scientists have no influence on science" (56% agreed and 40% were not sure).

Results for items belonging to preservice teachers' perceptions regarding educational applications of NOS (Figs. 11 and 12) showed that items emphasizing "the importance of teaching students about scientific aims and values" (items 27 and 17) and encouraging "collaboration among students in science lessons" (item 29) all received the highest mean scores (3.93 and 3.95) across items for this scale. Around 59% of the respondents agreed with the need to "cover the social and cultural aspects of science" whereas 36% reported being not sure (item 55). Different views were obtained for item (68) "it is not necessary for students to understand how knowledge develops in science" (26% disagreed, 31% were not sure, and 43% agreed). Last, only a few participants (45%) agreed that "having students participate in discussions about data does not make a difference" (item 35) yielding the least mean score ($M=2.9$) (see data Table 12 in Appendix B).

The last research question (Q3) was devoted to investigating whether there were any differences in perceptions of NOS based on preservice teachers' year of study and whether they had previously received training in NOS. Results obtained from one-way analysis of variance test (Table 5) showed there was no statistically significant difference in NOS mean scores between teachers who had taken training on NOS and those who did not for the cognitive-episteme scale ($F(1)=1.533$, $p=0.218$), the social-institutional scale ($F(1)=0.000$, $p=0.996$), and the educational application scale ($F(1)=0.548$, $p=0.460$). Nevertheless,

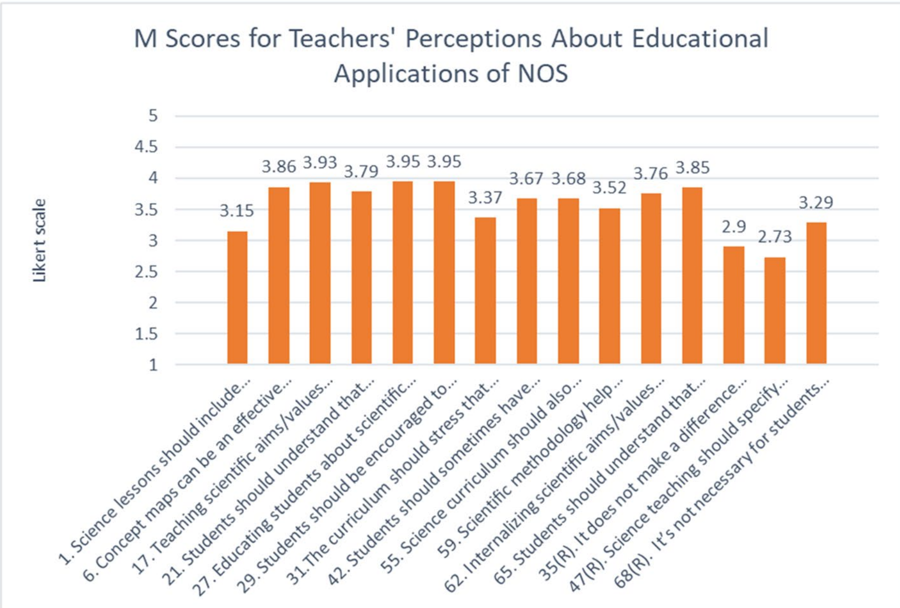


Fig. 11 *M* scores for perceptions about educational applications of NOS

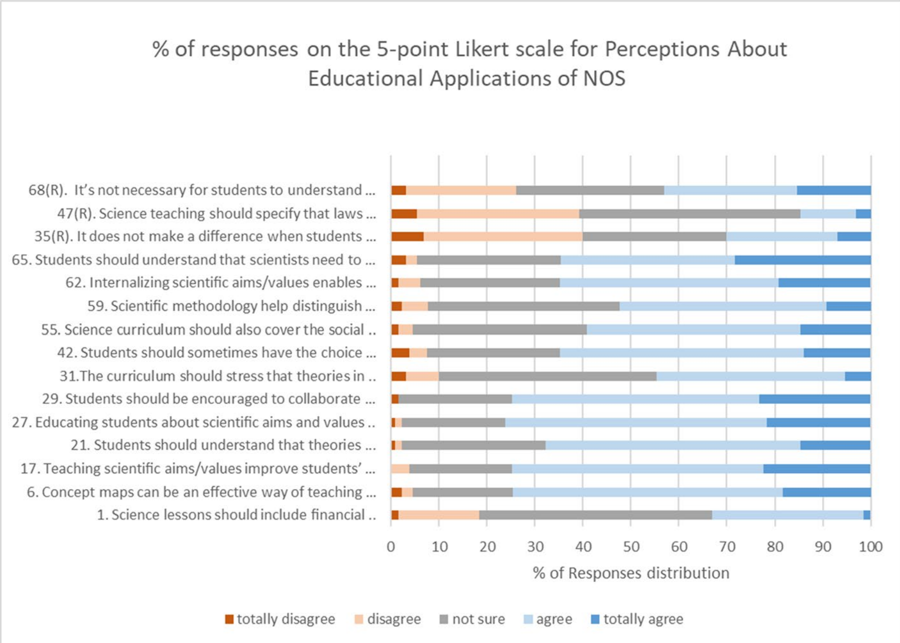


Fig. 12 % of responses on the 5-point Likert scale for perceptions about educational applications of NOS

Table 5 Results for one-way ANOVA for differences in NOS perceptions across the three scales on the NOS training variable

	Received training on NOS					
	Yes (*N*=30)		No (100)		*F*	Sig
Scale	*M*	*SD*	*M*	*SD*		
Cognitive-epistemic	3.42	0.29	3.35	0.24	1.53	0.22
Social-institutional	3.60	0.45	3.60	0.38	0.00	1.00
Educational application	3.51	0.39	3.57	0.37	0.55	0.46

results indicate that teachers who received NOS training had a higher mean value (3.42) on the cognitive-epistemic scale than those who did not receive training (3.34), whereas an equal mean value was obtained on the social-institutional scale for both groups (3.60). Teachers with no NOS training, however, scored slightly higher mean value (3.57) than the trained teachers' group (3.51) on the educational application scale.

With respect to the year of study as determined by one-way ANOVA results in Table 6, findings showed that there was no statistically significant difference in the mean scores of NOS perceptions between groups of preservice teachers across the 4 years of study for the cognitive-epistemic scale ($p=0.178$) and the social-institutional scale ($p=0.117$). The only statistically significant difference occurred for the educational application scale ($F(3,126)=2.899$, $p=0.038$). On a closer view, a Scheffé post hoc test, however, showed no differences between the participants' groups for this scale. Moreover, no clear trend can be observed over mean values across different years of study for the three scales, meaning there was no constant increase or decrease in the mean scores as the participants

Table 6 Results for one-way ANOVA for differences in NOS perceptions across the three scales on the year of study variable

	Year of study									
	First year ($N=12$)		Second year ($N=41$)		Third year ($N=41$)		Last year ($N=36$)		F	Sig
Scale	M	SD	M	SD	M	SD	M	SD		
Cognitive-epistemic	3.39	0.27	3.42	0.28	3.30	0.19	3.37	0.27	1.66	0.178
Social-institutional	3.67	0.33	3.70	0.47	3.50	0.36	3.57	0.34	2.00	0.117
Educational application	3.64	0.312	3.68	0.40	3.48	0.32	3.47	0.39	2.90	0.038

transitioned from their first year to the last year of study. Yet, an increase in mean values on all three scales can be witnessed in their second year, which decreased again in their third year. In the last year, mean values increased again for the cognitive-epistemic scale (from 3.30 to 3.37) and social-institutional scale (from 3.50 to 3.57) but slightly decreased for the educational application scale (from 3.48 to 3.47).

5 Discussion

Overall, key findings from the current study demonstrate that the sampled UAE preservice teachers appeared to have more informed conceptions of the social-institutional aspects of NOS ($M=3.60$) which highlight issues pertaining to the social, cultural, financial, political, and contextual aspects of science, as well as on the educational applications of NOS ($M=3.55$) compared to their perceptions about the cognitive-epistemic aspects of NOS ($M=3.37$). These findings match those observed in earlier studies on NOS perceptions indicating that preservice teachers who are enrolled in non-science fields have well-informed perceptions, particularly for the social and institutional systems of science (e.g., Kaya et al., 2019; Liu & Tsai, 2008; Parker et al., 2008). As Akgun and Kaya (2020) explained, a possible reason could be that students from non-science majors often learn about a variety of multidisciplinary topics that are subsumed in social science disciplines such as humanities and philosophy, and thus, they are expected to develop an understanding of societal and cultural issues. This may be true for the current participants who undertake such courses as part of the Early Childhood Education program, namely, the Family, Community, Culture and Early Childhood Education; Development of Religious and Social Concepts in ECE; Introduction to Philosophy, Introduction to Heritage and Culture; and History and Theories of Contemporary Architecture.

Looking closer at the cognitive-epistemic subscales, the scientific methods ($M=3.13$) and scientific knowledge ($M=3.33$) obtained the least mean score. However, teachers scored higher on items tapping into the scientific aims and values ($M=3.38$). This result ties in well with findings of Azninda and Sunarti's (2021) study where the scientific methods were the least scored category in the RFN. Having somehow a limited background in NOS in this sense should not be a surprise given that, as noted above, the participants in this study are not majoring in science and therefore may not have a sophisticated and deep understanding of the epistemological and procedural nature of NOS. Previous evidence would support this as it has been shown that students' academic majors play an important role in impacting their perceptions of NOS (Akgun & Kaya, 2020; Leung et al., 2015; Liu & Tsai, 2008; Parker et al., 2008; Yilmaz-Tuzun, 2008). Typically, the content of the specialized science courses usually draws more upon the cognitive aspects of science and are expected to intensively expose students to opportunities that engage them with the methodological approaches in science (e.g., observational methods, hypothesis testing, and manipulative/non-manipulative investigations), compared to science courses undertaken in educational-oriented disciplines. This potentially can affect the students' science-based knowledge, practices, and experiences.

Specifically, preservice teachers acknowledged the importance of considering scientific aims and values as part of the science curriculum (e.g., epistemic, cognitive, social, cultural, political, and ethical values). This consideration is quite influential in NOS learning basically because values and science intersect naturally and inevitably (Allchin, 1999). In other words, values act as filters that shape the science methodological rules, decisions, approaches, and interpretations. Therefore, they mediate the knowledge construction and development processes (Erduran & Dagher, 2014). It is important that teachers have a comprehensive understanding of scientific values such as objectivity, accuracy, honesty, respect for human needs, and respect for the environment to be able to purposefully and thoughtfully incorporate them into their teaching (McComas, 1998). Otherwise, little can be done to promote and exemplify these values in science teaching for young children (Erduran et al., 2018; Longino, 1990).

Furthermore, the participating preservice teachers highly rated items denoting the various forms of social interactions and activities among scientists (e.g., participation in conferences for sharing research work, interacting with other scientists while doing research, and writing papers in academic journals). They also highly agreed with the need to foster collaboration among students in science lessons as evident in the high mean scores for these items (above 3.72). A similar pattern of results was obtained in Saleh and Khine's (2014) study which reported that the majority of the UAE preservice teacher education students believed that science reflects social aspects, and this was attributed to the integrated curriculum in some schools in the UAE (e.g., integrating social science courses with the hard sciences like biology). Akgun and Kaya (2020) however found that only 58% of the non-science majors' students have recognized the professional and academic collaborative activities among scientists such as the peer-reviewing process and sharing findings with the public through articles, journals, social media, and TV. In essence, such socialization activities are integral in science learning as they depict how scientists share, discuss, argue, and present their results in front of other people, leading to a richer, socially co-constructed knowledge. The point that science is not solitary or an individual pursuit needs to be visible for children in the early years.

Additionally, results demonstrated that the majority of the preservice teachers acknowledged the contribution of scientific practices, namely, the necessity for scientists to question their ideas if not empirically supported, the role of classification and models in understanding complex phenomena, and the need for scientists to review and assess each other's work against standards specified for evaluation. However, teachers seemed to agree less with the effect of bias and prejudice on scientific knowledge, the role of politics in the practices of science and the growth of scientific knowledge, and the consideration of science as a social system. Previous findings, for instance, also found that teachers rarely considered the influence of political power structures on science and were not able to relate them to one another (Akgun & Kaya, 2020). Moreover, it is expected that teachers may not be aware that bias is inherent within various aspects of the scientific enterprise due to the common mistaken notion that knowledge of the natural world is completely objective;

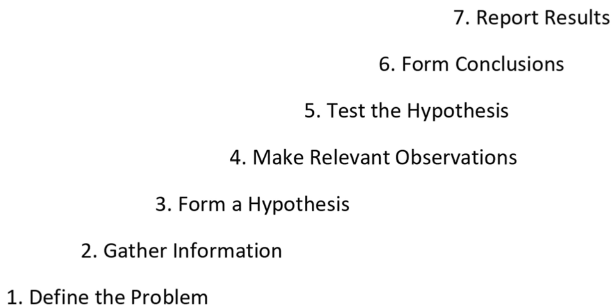
thus, it is independent of the searching individual (Erduran & Dagher, 2014). Meaning that as scientists engage in their work, they are expected to bracket aside their personal biases, prejudices, and beliefs so they become able to make observations, conduct investigations, evaluate new evidence, and draw conclusions in a bias-free, "objective" manner. Building on this, it is important for teachers to understand the different types of bias that scientists might be experiencing or getting exposed to, their sources, and their implications (McComas, 1998).

In addition, around 77% of preservice teachers agreed with the notion that experiments follow fixed procedures. This is a common misunderstanding of science experiments being perceived as following a fixed predetermined set of procedures, or what has been termed, the 'cookbook' approach (Erduran & Dagher, 2014). This misconception often results in students "doing" experiments following recipes of steps without having thoughtful reflections on the scientific practices they are implementing. In actuality, experiments are carried out in several ways. For instance, astronomers do not do experiments on distant objects such as stars in space, neither can they manipulate those, meaning that science does not have to involve experimentation (Erduran & Dagher, 2014). Indeed, the emergent nature of the science work is highly contextualized, and thus, cannot be fully controllable or predictable.

Furthermore, only 41% of preservice teachers believed that there is no step-by-step order to doing science (37% reported not being sure), and only 35% believed that there is no universal scientific method which is ought to be followed by all scientists and across all scientific disciplines (52% reported not being sure). Embracing the stereotypical depiction of the scientific method among preservice teachers is repeatedly reported in previous studies (e.g., Akgun & Kaya, 2020; Ioannidou & Erduran, 2021; Kartal et al., 2018; Woodcock, 2014; Zion et al., 2020). This belief is underpinned by the positivism views of learning (e.g. Abd-El-Khalick & Lederman, 2000), which are still dominant in science textbooks that often illustrate scientific methods as a linear model, or a common series of steps starting with defining the problem, followed by gathering information, forming a hypothesis, making observations, testing the hypothesis, and ending with drawing conclusions in addition to communicating results in some other versions (see Fig. 13 adapted from McComas, 1998). It is true that scientists may decide to adopt new procedures or alter the approach of their investigations, or even add new research questions which could extend the scope of questions that were initially considered. They work synergistically using different tools and approaches together as they see appropriate to solve problems in order to obtain a variety of evidence (Wivagg & Allchin, 2002).

Although the preservice teachers in the current study were aware that there are different kinds of theories (M = 3.75), they seem to have a confused understanding of the difference

Fig. 13 The traditional linear model of scientific methods (adapted from McComas, 1998)



between laws and theories as indicated by responses to the corresponded items (16, 43, and 66). Lacking this sort of NOS understanding has been addressed in several previous studies (Akerson et al., 2006; Dagher et al., 2004; Kaya, 2012; Lederman et al., 2002; McComas, 1998; Miller et al., 2010). Saleh and Khine (2014) also found that teacher education students in the UAE had ill-informed or ambiguous views in this regard. This is also consistent with the findings of Akgun and Kaya (2020) which reported that preservice teachers had uninformed views about the differences between scientific theories and laws. Recognizing the different levels of theories (e.g., established verses fringe theories), both within a particular science topic or across multiple topics and disciplines, and understanding the distinct classifications of different forms of knowledge, is a foundational prerequisite knowledge for science teachers so that they can capture the empirical, logical, and mathematical bases of scientific knowledge (Erduran & Dagher, 2014).

For the current sample, there were no statistically significant differences in NOS understanding relating to whether the participant had received any formal training in NOS for the cognitive-epistemic scale ($p = 0.218$), the social-institutional scale ($p = 0.996$), and the educational application scale ($p = 0.460$). This finding accords with prior findings indicating that although taking courses or training on NOS proved to be successful in some occasions, it does not necessarily contribute to making student teachers' conceptions more sophisticated (e.g., Celik & Bayrakceken, 2012; Krell et al., 2015; Mesci & Schwartz, 2017). In principle, both the quantity and the quality of NOS training are essential to attain a progressive understanding of NOS, as well as to help preservice teachers adopt effective approaches and develop the necessary set of skills required (Leung et al., 2015). Accordingly, taking only a few training workshops on teaching NOS may not be sufficient for altering and enhancing preservice teachers' understanding.

6 Conclusion and Implications for Practice

This study was conceptually grounded in the Reconceptualised Family Resemblance Approach to Nature of Science (RFN) (Erduran & Dagher, 2014) as a holistic framework to investigate the NOS perceptions held by the UAE preservice science teachers. Based on the current findings, teachers appeared to acknowledge issues pertaining to the social-institutional aspects of NOS more than the cognitive-epistemic aspects. An informed perception of certain aspects of NOS across the NOS scales and subscales existed. However, a number of misconceptions on other aspects of NOS were recognized and in line with findings from previous studies addressing similar improper understanding (e.g., Abd-El-Khalick & Lederman, 2000; Aflalo, 2018; Akerson et al., 2000; Bilican et al., 2015; Karaman, 2018; Kaya, 2012; Nur & Fitnat, 2015; Sahin & Deniz, 2016).

Overall, the analysis of data derived from the RFN tool in this study provides a thorough understanding of views about NOS that are held by the participating preservice teachers who are enrolled in a teacher education program and are working toward teacher certification to become practicing teachers for early childhood and primary learning stages. With the increased focus on improving Early Childhood Education programs, there is a need for curriculum developers to re-evaluate the coverage of NOS-related topics and assess the instructors' pedagogical approach for teaching and engaging students with these topics within the designed structure of the preservice teachers' course of study. This is especially needed in the current context given that the undergraduate students majoring in Early Childhood Education only briefly tackle NOS as part of the program, although they attend several courses relevant to science (e.g., science education for young children, natural science, and biology and its modern application). The program coordinators, therefore, need to ensure the development of proper awareness and capabilities for sophisticated understanding and teaching of NOS progressively across years of study, through practical and situated examples that link science with the ethos and practices of the scientific community, as well as with the economic, social, and political influences at the local, national, and international levels. Additional curriculum goals could be added to address NOS content, especially those which are typically observed as scientifically essential in science teaching targeting young children.

7 Limitations and Future Research

The current study was based in the UAE and involved preservice education teachers who were trained to teach in kindergarten and elementary school stages (KG to Grade 5/FS1 to Year 4); therefore, the extent to which the current results can be generalized to preservice teachers from other majors or other settings is not clear. A natural extension of the current work could involve document analysis of the university science-related courses in an attempt to assess the representation of the NOS structures within the curriculum sections to see if these are sufficiently and appropriately addressed. Moreover, given that the reported findings were drawn from a self-report measure using the RFN questionnaire, obtaining an understanding that is multifaceted of the obtained perceptions held by the participants from multiple dimensions is still lacking. This is due to the fact that it cannot be directly inferred from the numerical data generated by means of scale items in the standardized questionnaires (Creswell & Plano Clark, 2011), which calls for further interpretive in-depth qualitative investigation. Lastly, the current study did not investigate how preservice teachers may apply key aspects of NOS embedded in the questionnaire items into their actual teaching, which indeed deserves further investigation. Hence, to better address the educational application category of the RFN framework, triangulation of data is believed to enable the examination of teachers' implementation of the RFN framework as part of instructional pedagogies of science teaching. This step holds promise in helping move research into the practical direction that is associated with NOS teaching and learning.

Appendix 1. RFN questionnaire items (from Kaya et al., 2019)

1. Science lessons should include financial (economical) aspects of science
2. Epistemic, cognitive, and cultural values of science cannot be distinctly distinguished from each other
3. Scientific knowledge does not change
4. Scientists review and assess each other's work
5. The power of experimentation comes from testing a scientific hypothesis many times by scientists
6. Concept maps can be an effective way of teaching classification as scientific practice
7. Science takes place in institutions such as universities and research centers
8. All scientific disciplines such as physics, biology, and chemistry use the same scientific method
9. Science is a social system
10. Scientific progress occurs when ideas are evaluated and revised

11. Each branch of science has a different nature
12. Students should determine the methods of their science investigations themselves
13. Politics does not influence science
14. Scientists should respect the environment
15. Analysis and interpretation of data are components of scientific practices
16. Theories and laws are forms of scientific knowledge but models are not
17. Teaching scientific aims and values of science is likely to improve students' understanding of science
18. Scientists do not have to share their research with society
19. Scientists build and use models to understand complex scientific phenomena
20. The diversity of scientists solving a problem together means less biased results
21. Students should understand that theories are a collection of models
22. There is no step by step order to doing science
23. All branches of science use observations
24. Diversity of methods contributes to scientific understanding
25. All hypothesis testing is manipulative
26. Some branches of science do not use representations
27. Educating students about scientific aims and values improves scientific literacy
28. Scientists have to use different methods to produce enough evidence so that they can solve problems
29. Students should be encouraged to collaborate with their peers in science lessons because scientists collaborate with other scientists when doing research
30. Scientific knowledge consists of a coherent set of ideas
31. The curriculum should stress that theories in chemistry and physics are the same
32. Scientists need money to do research
33. Classification helps scientists explain and predict phenomena
34. All scientific disciplines such as physics, biology, and chemistry produce values that can contribute to society
35. It does not make a difference to students' learning of science when they participate in discussions about experimental data
36. The gender of scientists influences how they do science
37. There is a universal scientific method that all scientists use all over the world
38. Scientific experiments follow a certain set of procedures
39. Intellectual honesty in science does not have to be taught in science lessons
40. Scientists should change their minds when they realize that their ideas are not supported by evidence
41. Policies of governments affect the growth of scientific knowledge
42. Students should sometimes have the choice to design methods for their investigations
43. Laws are theories that are confirmed
44. Scientific models are tools to represent the real world
45. Some scientists earn more money than others, causing tension between scientists
46. Scientific facts are not affected by bias and individual subjective prejudices of scientists
47. Science teaching should specify that laws are certain and unchangeable
48. Race and ethnicity of scientists have nothing to do with science
49. Changing variables is a fundamental requirement for a scientific study
50. Theories, laws, and models work together to produce scientific knowledge
51. Teaching epistemic, cognitive, social, and cultural values should be the core components of the science curriculum
52. Different branches of science like physics, biology, and chemistry have the same practices
53. Scientists write papers in academic journals
54. There are different kinds of theories. Some are accepted; others are still debated

55. Science curriculum should not only cover scientific knowledge but also the social and cultural aspects of science
56. There is no relationship between scientific facts and values
57. Scientists from all branches of science validate scientific knowledge by evaluating each other's ideas
58. Scientists participate in conferences to share their research with other scientists
59. Understanding scientific methodology can help students distinguish between science and non-science
60. All scientific disciplines such as physics, biology, and chemistry require constructing hypotheses
61. There are standards for evaluating the quality of scientific work
62. Internalizing scientific aims and values enables students to understand scientific knowledge
63. Models can help scientists to explain and predict phenomena
64. Scientific practices produce knowledge and are not influenced by cultural factors
65. Students should understand that scientists need to have social values such as honesty
66. Laws are more verifiable scientific knowledge than theories
67. There are social hierarchies among science teams and these can change
68. It is not necessary for students to understand how knowledge develops in science
69. Scientific aims and values affect scientists' choice of methods in their investigations
70. Scientists socially interact with other scientists while doing research

Appendix 2

Table 7 Descriptive statistics and response distribution for aims and value category

Teachers' perceptions about aims and values of science							
Item	Mean	SD	Responses distribution of the items *f*(%)				
			Totally disagree	Disagree	Not sure	Agree	Totally agree
2. Epistemic/cultural values of science cannot be distinguished …	3.06	0.78	0 (0)	34 (26.2)	55 (42.3)	40 (30.8)	1 (0.8)
20. The diversity of scientists solving a problem …	3.55	0.95	3 (2.3)	14 (10.8)	41 (31.5)	53 (40.8)	19 (14.6)
40. Scientists should change their minds …	3.69	0.88	4 (3.1)	4 (3.1)	40 (30.8)	62 (47.7)	20 (15.4)
51. Teaching scientific values should be the core components …	3.69	0.84	2 (1.5)	4 (3.1)	48 (36.9)	54 (41.5)	22 (16.9)
69. Scientific aims and values affect scientists' choice …	3.68	0.80	3 (2.3)	1 (0.8)	48 (36.9)	61 (46.9)	17 (13.1)
46(R)*. Scientific facts are not affected by bias …	2.79	0.77	3 (2.3)	42 (32.3)	68 (52.3)	13 (10.0)	4 (3.1)
56(R). There is no relationship between scientific facts …	3.21	0.93	6 (4.6)	16 (12.3)	64 (49.2)	33 (25.4)	11 (8.5)

*(R) indicates the reversed items corresponding to the negative items in the questionnaire

Table 8 Descriptive statistics and response distribution for scientific practice category

Teachers' perceptions about scientific practices							
Item	Mean	SD	Response distribution of the items *f*(%)				
			Totally disagree	Disagree	Not sure	Agree	Totally agree
4. Scientists review and assess each other's work	3.82	0.71	1 (0.8)	1 (0.8)	37 (28.5)	72 (55.4)	19 (14.6)
5. The power of experimentation comes from several …	3.78	0.81	1 (0.8)	7 (5.4)	32 (24.6)	69 (53.1)	21 (16.2)
15. Analysis and interpretation of data are components …	3.89	0.76	1 (0.8)	4 (3.1)	27 (20.8)	74 (56.9)	24 (18.5)
19. Scientists build and use models to understand.	3.90	0.76	1 (0.8)	1 (0.8)	35 (26.9)	66 (50.8)	27 (20.8)
23. All branches of science use observations	3.92	0.67	0 (0)	2 (1.5)	28 (21.5)	78 (60.0)	22 (16.9)
33. Classification helps scientists explain and predict phenomena	3.75	0.83	2 (1.5)	5 (3.8)	38 (29.2)	64 (49.2)	21 (16.2)
38. Scientific experiments follow a certain set of procedures	3.66	0.76	1 (0.8)	4 (3.1)	49 (37.7)	60 (46.2)	16 (12.3)

Table 8 (continued)

Teachers' perceptions about scientific practices

Item	Mean	SD	Response distribution of the items $f(\%)$				
			Totally disagree	Disagree	Not sure	Agree	Totally agree
57. Scientists from all branches of science validate …	3.78	0.84	2 (1.5)	4 (3.1)	39 (30.0)	61 (46.9)	24 (18.5)
61. There are standards for evaluating the quality of scientific work	3.89	0.78	1 (0.8)	3 (2.3)	32 (24.6)	67 (51.5)	27 (20.8)
63. Models can help scientists to explain and predict phenomena	3.90	0.88	1 (0.8)	7 (5.4)	30 (23.1)	58 (44.6)	34 (26.2)
26(R). Some branches of science do not use representations	2.85	0.92	5 (3.8)	43 (33.1)	57 (43.8)	17 (13.1)	8 (6.2)
52(R). Different branches of science have the same practices	2.58	0.89	9 (6.9)	60 (46.2)	39 (30.0)	20 (15.4)	2 (1.5)
64(R). Scientific practices produce knowledge and …	2.42	0.85	18 (13.8)	51 (39.2)	52 (40.0)	7 (5.4)	2 (1.5)

*(R) indicates the reversed items corresponding to the negative items in the questionnaire

Table 9 Descriptive statistics and response distribution for scientific method category

Teachers' perceptions about scientific methods							
Item	Mean	SD	Response distribution of the items *f*(%)				
			Totally disagree	Disagree	Not sure	Agree	Totally agree
11. Each branch of science has a different nature	3.85	0.80	3 (2.3)	3 (2.3)	26 (20.0)	77 (59.2)	21 (16.2)
22. There is no step by step order to doing science	3.19	0.90	4 (3.11)	25 (19.2)	48 (36.9)	48 (36.9)	5 (3.8)
24. Diversity of methods contributes to scientific understanding	3.90	0.79	0 (0)	4 (3.1)	35 (26.9)	61 (46.9)	30 (23.1)
28. Scientists have to use different methods to produce …	3.97	0.80	0 (0)	3 (2.3)	34 (26.2)	57 (43.8)	36 (27.7)
8(R). All scientific disciplines use the same scientific method	2.74	0.83	3 (2.3)	55 (42.3)	47 (36.2)	23 (17.7)	2 (1.5)
25(R). All hypothesis testing is manipulative	2.95	0.93	4 (3.1)	38 (29.2)	59 (45.4)	19 (14.6)	10 (7.7)
37(R). There is a universal scientific method that all scientists …	2.73	0.84	10 (7.7)	35 (26.9)	68 (52.3)	14 (10.8)	3 (2.3)

Table 9 (continued)

Teachers' perceptions about scientific methods

Item	Mean	SD	Response distribution of the items *f*(%)				
			Totally disagree	Disagree	Not sure	Agree	Totally agree
49(R). Changing variables is a fundamental requirement …	2.58	0.78	8 (6.2)	50 (38.5)	63 (48.5)	6 (4.6)	3 (2.3)
60(R). All scientific disciplines require constructing hypotheses	2.25	0.90	23 (17.7)	64 (49.2)	36 (27.7)	2 (1.5)	5 (3.8)

*(R) indicates the reversed items corresponding to the negative items in the questionnaire

Table 10 Descriptive Statistics and Responses Distribution for Scientific Knowledge Category

Teachers' perceptions about scientific knowledge							
Item	Mean	SD	Response distribution of the items *f*(%)				
			Totally disagree	Disagree	Not sure	Agree	Totally agree
10. Scientific progress occurs when ideas are evaluated …	3.86	0.73	1 (0.8)	1 (0.8)	36 (27.7)	69 (53.1)	23 (17.7)
30. Scientific knowledge consists of a coherent set of ideas	3.93	0.68	1 (0.8)	1 (0.8)	26 (20.0)	80 (61.5)	22 (16.9)
44. Scientific models are tools to represent the real world	3.74	0.91	4 (3.1)	6 (4.6)	33 (25.4)	64 (49.2)	23 (17.7)
50. Theories, laws, and models work together to produce …	3.83	0.80	1 (0.8)	3 (2.3)	39 (30.0)	61 (46.9)	26 (20.0)
54. There are different kinds of theories. Some are …	3.75	0.83	3 (2.3)	4 (3.1)	35 (26.9)	69 (53.1)	19 (14.6)
3(R). Scientific knowledge does not change	3.45	0.98	4 (3.1)	17 (13.1)	43 (33.1)	49 (37.7)	17 (13.1)
16(R). Theories and laws are forms of scientific …	2.72	0.82	9 (6.9)	39 (30.0)	63 (48.5)	18 (13.8)	1 (0.8)
43(R). Laws are theories that are confirmed	2.25	0.92	28 (21.5)	54 (41.5)	39 (30.0)	6 (4.6)	3 (2.3)

Table 10 (continued)

Teachers' perceptions about scientific knowledge							
Item	Mean	SD	Response distribution of the items *f*(%)				
			Totally disagree	Disagree	Not sure	Agree	Totally agree
66(R). Laws are more verifiable scientific knowledge.	2.42	0.80	15 (11.5)	55 (42.3)	53 (40.8)	5 (3.8)	2 (1.5)

*(R) indicates the reversed items corresponding to the negative items in the questionnaire

Table 11 Descriptive statistics and response distribution for social-institutional aspects of science

Teachers' perceptions about social-institutional aspects of science							
Item	Mean	SD	Response distribution of the items f(%)				
			Totally disagree	Disagree	Not sure	Agree	Totally agree
7. Science takes place in institutions such as …	3.89	0.72	1 (0.8)	2 (1.5)	29 (22.3)	76 (58.5)	22 (16.9)
9. Science is a social system	3.51	0.74	0 (0)	11 (8.5)	50 (38.5)	61 (46.9)	8 (6.2)
14. Scientists should respect the environment	4.22	0.81	1 (0.8)	2 (1.5)	19 (14.6)	54 (41.5)	54 (41.5)
32. Scientists need money to do research	3.69	0.86	1 (0.8)	7 (5.4)	47 (36.2)	51 (39.2)	24 (18.5)
34. All scientific disciplines produce values …	3.70	0.91	2 (1.5)	10 (7.7)	37 (28.5)	57 (43.8)	24 (18.5)
41. Policies of governments affect the growth of …	3.49	0.86	2 (1.5)	12 (9.2)	50 (38.5)	52 (40.0)	14 (10.8)
45. Some scientists earn more money than others, …	3.34	0.88	3 (2.3)	14 (10.8)	61 (46.9)	40 (30.8)	12 (9.2)
48. Race and ethnicity of scientists have nothing to do …	3.69	0.07	2 (1.5)	3 (2.3)	52 (40.0)	49 (37.7)	24 (18.5)

Table 11 (continued)

Teachers' perceptions about social-institutional aspects of science

Item	Mean	SD	Response distribution of the items *f*(%)				
			Totally disagree	Disagree	Not sure	Agree	Totally agree
53. Scientists write papers in academic journals	3.72	0.76	2 (1.5)	3 (2.3)	40 (30.8)	70 (53.8)	15 (11.5)
58. Scientists participate in conferences to share …	3.77	0.83	3 (2.3)	3 (2.3)	36 (27.7)	67 (51.5)	21 (16.2)
67. There are social hierarchies among science teams …	3.57	0.77	2 (1.5)	4 (3.1)	54 (41.5)	58 (44.6)	12 (9.2)
70. Scientists socially interact with other scientists …	3.72	0.82	4 (3.1)	1 (0.8)	39 (30.0)	69 (53.1)	17 (13.1)
13(R). Politics does not influence science	2.96	0.98	8 (6.2)	31 (23.8)	59 (45.4)	22 (16.9)	10 (7.7)
18(R). Scientists do not have to share their research with …	3.74	1.06	2 (1.5)	19 (14.6)	25 (19.2)	49 (37.7)	35 (26.9)
36(R). The gender of scientists influences how they do.	3.21	1.08	8 (6.2)	25 (19.2)	44 (33.8)	38 (29.2)	15 (11.5)
39(R). Intellectual honesty in science does not have …	3.35	1.02	4 (3.1)	22 (16.9)	48 (36.9)	37 (28.5)	19 (14.6)

*(R) indicates the reversed items corresponding to the negative items in the questionnaire

Table 12 Descriptive statistics and response distribution for educational applications of NOS

Teachers' perceptions about educational applications of NOS							
Item	Mean	SD	Response distribution of the items *f*(%)				
			Totally disagree	Disagree	Not sure	Agree	Totally agree
1. Science lessons should include financial …	3.15	0.77	2 (1.5)	22 (16.9)	63 (48.5)	41 (31.5)	2 (1.5)
6. Concept maps can be an effective way of teaching …	3.86	0.82	3 (2.3)	3 (2.3)	27 (20.8)	73 (56.2)	24 (18.5)
17. Teaching scientific aims/values improve students' …	3.93	0.77	0 (0)	5 (3.8)	28 (21.5)	68 (52.3)	29 (22.3)
21. Students should understand that theories …	3.79	0.73	1 (0.8)	2 (1.5)	39 (30.0)	69 (53.1)	19 (14.6)
27. Educating students about scientific aims and values …	3.95	0.75	1 (0.8)	2 (1.5)	28 (21.5)	71 (54.6)	28 (21.5)
29. Students should be encouraged to collaborate …	3.95	0.78	2 (1.5)	0 (0)	31 (23.8)	67 (51.5)	30 (23.1)
31.The curriculum should stress that theories in …	3.37	0.82	4 (3.1)	9 (6.9)	59 (45.4)	51 (39.2)	7 (5.4)
42. Students should sometimes have the choice …	3.67	0.90	5 (3.8)	5 (3.8)	36 (27.7)	66 (50.8)	18 (13.8)
55. Science curriculum should also cover the social …	3.68	0.82	2 (1.5)	4 (3.1)	47 (36.2)	58 (44.6)	19 (14.6)
59. Scientific methodology help distinguish …	3.52	0.83	3 (2.3)	7 (5.4)	52 (40.0)	56 (43.1)	12 (9.2)
62. Internalizing scientific aims/values enables …	3.76	0.87	2 (1.5)	6 (4.6)	38 (29.2)	59 (45.4)	25 (19.2)
65. Students should understand that scientists need to …	3.85	0.97	4 (3.1)	3 (2.3)	39 (30.0)	47 (36.2)	37 (28.5)
35(R). It does not make a difference when students …	2.90	0.09	9 (6.9)	43 (33.1)	39 (30.0)	30 (23.1)	9 (6.9)
47(R). Science teaching should specify that laws …	2.73	0.85	7 (5.4)	44 (33.8)	60 (46.2)	15 (11.5)	4 (3.1)
68(R). It is not necessary for students to understand …	3.29	1.08	4 (3.1)	30 (23.1)	40 (30.8)	36 (27.7)	20 (15.4)

*(R) indicates the reversed items corresponding to the negative items in the questionnaire

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