Science students’ understanding of the Nature of Science in higher education: A Norwegian case study

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Abstract: Views of the Nature of Science (NOS) among science students in higher education is investigated in a Norwegian university. The research utilizes the Views of the Nature of Science questionnaire version D+ (VNOS-D+), conducting a comprehensive analysis of NOS perspectives among 41 participants in STEM courses during the autumn semester of 2023. An overall decent understanding of NOS was found among all participating science students, regardless of gender, country of origin or study program. The mean values of the results for each aspect of NOS fluctuate between 1.39 and 2.68 on a scale from 0 (inadequate), 1 (naïve), 2 (transitional), to 3 (adequate) and are distributed rather homogeneously ($\bar{x} = 2.02$), although the aspect of law and theory stands out for its prevalence of naïve responses ($\bar{x} = 1.39$). No significant improvement in NOS understanding was observed with increased academic tenure in this study. The study shows promising usefulness of the VNOS-D+ questionnaire in higher education, as a valuable tool for gaining standardized insights into NOS perspectives. This research contributes to the discourse on science education by examining science students’ understandings of NOS in higher education in a previously rarely examined location.

1 Introduction

The development of students' understanding of the Nature of Science (NOS) is crucial for educating science-literate citizens and has become an important goal for science education (Abd-El-Khalick & Lederman, 2000; Kostøl et al., 2023; Pavez et al., 2016). NOS is a hybrid field that combines aspects of various social studies of science, including the history, sociology, and philosophy of science with research from cognitive sciences such as psychology (Clough, 2006; Khishfe, 2023; Lederman, 1992; McComas, 1998). NOS provides a comprehensive description of “what science is, how it works, how scientists operate as a social group, and how society itself responds to scientific endeavours” (McComas et al., 1998, p. 4). Consequently, NOS involves a reflective understanding of the role of the natural sciences in a social context and the characteristics of scientific knowledge (Billion-Kramer et al., 2020).

Several studies have revealed that many of the common beliefs held by students and teachers about NOS include misunderstandings of NOS concepts (Abd-El-Khalick & Lederman, 2000; Anggoro et al., 2022; Bell & Lederman, 2003; Eastwood et al., 2012; Irez, 2006; Khishfe, 2020; Lederman, 2007; Narbona et al., 2023; Sevim & Pekbay, 2012; Sirait et al., 2022; Welter et al., 2023; Yaman & Nuhoglu, 2010). For example, “Science and those who do science can and should be free from emotions and bias,” “Scientific models are exact copies of reality,” and “Science research follows a step-by-step scientific method and carefully adhering to this systematic method accounts for the success of science” are some common misconceptions (Clough, 2017, p. 41). This lack of NOS understanding is potentially harmful to society and leads to numerous misleading decisions and unreasonable positions (McComas et al., 1998). The use of research-based methods in education enables a discussion and integration of fundamental considerations for teaching NOS explicitly in the classroom. Research-based science education also encourages student reflection and ensures a degree of contextualisation (McComas et al., 2020). Consequently, the application of research-based methods in education can support a more accurate understanding of NOS conceptions (Fergusson et al., 2020; Gathong & Chamrat, 2019; Kahana & Tal, 2014).

Although NOS is an important topic in science education in schools and universities, certain regions, such as Norway, have not yet been sufficiently investigated. Additionally, research in the field of NOS is predominantly focusing on the context of school and teacher education. For these reasons, the purpose of this study is to provide insights into the currently prevailing views of NOS among science students in higher education, specifically in Norway. Furthermore, the collected data is compared with a selection of comparable international studies to identify similarities and differences. Subsequently, this provides answers to the two following research questions:

RQ1: To what extent do these students understand the conceptions of NOS?

RQ2: Does our students’ understanding of NOS differ from that of students from other countries?

2 Theoretical framework

The concept of NOS encompasses the epistemology and sociology of science, focusing on how science serves to understand the natural world and the influence of values and beliefs within the scientific community on the development of scientific knowledge (Lederman, 1992; Lederman & Lederman, 2004). NOS integrates elements from various social sciences, including history, sociology, and philosophy, as well as cognitive sciences like psychology, to provide a comprehensive understanding of the Nature of Science, its functioning, social dynamics, and its interaction with society. A precise and generally valid characterization of NOS-specific aspects is problematic, as there is no universally valid definition of the Nature of Science (Khishfe, 2023). Therefore, there are different modelling approaches such as the minimal consensus (e.g. Lederman et al., 2002; McComas & Olson, 1998; Osborne et al., 2003), Nature of Whole Science (e.g. Allchin, 2011), Family Resemblance Approach (e.g. Erduran & Dagher, 2014) and the narrative approach (e.g. Aduríz-Bravo, 2013), that attempt to provide this understanding. However, we will use the minimal consensus approach in this study, as this approach is particularly suitable for embedding NOS in a comprehensive understanding of education (Heering & Kremer, 2018), and the selected methodology is based on this approach (Lederman et al., 2002; Lederman et al., 2013).

According to the minimal consensus, Nature of Science encompasses that scientific knowledge is empirical, that scientific knowledge is subjective, that science necessarily involves human inference, imagination, and creativity, that scientific knowledge is never absolute or certain, and that science is socially and culturally embedded (Lederman et al., 2013). Two additional important aspects of NOS are the distinction between observation and inference and the distinction between scientific laws and theories (Clough, 2006; Lederman et al., 2002; McComas, 2015). This results in seven characteristic aspects of NOS (see table 1).

Integrating NOS into science education at school and university serves multiple objectives. These include enhancing pedagogical content knowledge, distinguishing between STEM and non-STEM disciplines, recognizing the strengths and limitations of scientific knowledge, promoting scientific literacy, and fostering students' interest in science through practical and investigative experiences (Bell, 2008; Chaiyabang & Thathong, 2014; Vhurumuku, 2010). One important goal of NOS is to enable learners to critically evaluate pseudo-scientific claims (Khishfe, 2023). This approach might ignite learners' interest in science, promote scientific literacy and ethical reflection, and encourage students to apply scientific knowledge to personal and global decision-making, including participating in discussions (Bell, 2008; Hodson & Wong, 2014). For example, to accept the theory of evolution, students have (1) to understand the differences between religious belief and scientific knowledge, (2) to be able to differentiate between science and pseudoscience, and (3) to understand the epistemological status of a theory (Sinatra et al., 2003).

By incorporating aspects of NOS into science education there is an opportunity to meet the above educational objectives. However, in addition to affecting students' understanding of NOS, science education must provide not only tasks such as doing science, but also logical reasoning that drives this science (Alisir & Irez, 2020; Bell et al., 2003; Khishfe & Abd-El-Khalick, 2002). The large proportion of views of NOS mentioned earlier may lead to misconceptions in the overall understanding of NOS (Billion-Kramer et al., 2020; Cofré et al., 2019; Lederman, 2007). Besides that, it is important to teach NOS in a reflective and explicit way by making aspects of science visible in the classroom (Lederman, 2006; Webb, 2007). Knowledge of NOS is therefore essential to ensure that complex NOS concepts are communicated clearly and accurately to students. It also enables students to develop scientific literacy and contribute to quality science education. As part of successful practical application, for instance, students will be able to evaluate scientific findings presented in the media and draw conclusions from them. Furthermore, students will be able to assess the uncertainties associated with measurements from experiments and evaluate the effects of these uncertainties on the interpretation of the results.

Table 1: *Seven aspects of NOS according to Lederman et al., 2013.*

Aspect 1	Distinction between observations and inferences	Observations are descriptive statements about natural phenomena that are "directly" accessible to the senses (or extensions of the senses). By contrast, inferences are statements about phenomena that are not "directly" accessible to the senses.
Aspect 2	Empirical	Scientific knowledge is, at least partially, based on and/or derived from observations of the natural world.
Aspect 3	Creative and imaginative	Scientific knowledge involves human imagination and creativity. Science involves the invention of explanations, and this requires a great deal of creativity by scientists.
Aspect 4	Subjective	Scientific knowledge is subjective. Scientists' theoretical commitments, beliefs, previous knowledge, training, experiences, and expectations influence their work. Scientists' observations (and investigations) are always motivated and guided by and acquire meaning in reference to questions or problems. These questions or problems, in turn, are derived from within certain theoretical perspectives (theory-laden).
Aspect 5	Social and culture embeddedness	Science as a human enterprise is practiced in the context of a larger culture and its practitioners (scientists) are the product of that culture. Science, it follows, affects, and is affected by the various elements and intellectual spheres of the culture in which it is embedded. These elements include, but are not limited to, social fabric, power structures, politics, socioeconomic factors, philosophy, and religion.
Aspect 6	Tentative	Scientific knowledge is never absolute or certain. This knowledge, including "facts," theories, and laws, is tentative and subject to change. Scientific claims change as new evidence, made possible through advances in theory and technology, is brought to bear on existing theories or laws, or as old evidence is reinterpreted in the light of new theoretical advances or shifts in the directions of established research programs.
Aspect 7	Distinction between scientific laws and theories	Theories and laws are different kinds of knowledge, and one cannot develop or be transformed into the other. Laws are statements or descriptions of the relationships among observable phenomena. Theories, by contrast, are inferred explanations for observable phenomena.

3 Methodology

We applied the standardized test procedure VNOS-D+ from Lederman et al. (2010) to evaluate the *status quo* of science students' views of NOS at a Norwegian University. Following the suggestions from Lederman et al. (2010) we first conducted a detailed evaluation of each aspect of NOS. We then examined the overall evaluation using the same ranking scheme (see 3.3 Data Analyses).

The study was conducted at the University of Bergen (Norway), where a Centre for Excellence in Biology Education (bioCEED) has been working for ten years and focused on research-based learning to promote critical thinking, problem solving and collaboration.

All participating students gave their informed consent for inclusion before they took part in the study. The study was conducted in accordance with the Declaration of Helsinki. The Norwegian Agency for Shared Services in Education and Research (SIKT) approved the research procedures.

3.1 Participants

In the autumn semester of 2023, a survey was conducted with science students at the University of Bergen in Norway. The data were collected through a convenience sample of five STEM courses at the Faculty of Mathematics and Science. The choice of courses was based on their availability that semester. These courses are primarily at the master's level and are offered by the Department of Biosciences. The courses that were investigated mainly focused on biology, with one course on philosophy of sciences. Students from various education programs, including biology, molecular biology, and STEM teacher education were included in the survey. Altogether, 41 students participated in the survey. Of these students, 5 students were enrolled in a doctoral program (12.2%), 25 students in a master's program (61%) and 11 students in a bachelor's program (26.8%). The proportion of students in a STEM teaching degree was 17 students (41.5%), and the proportion of students in a professionalized biology degree was 24 students (58.5%). The gender distribution of the participants was 53.7% female and 46.3% male. No person identified themselves as any other gender. The participants have different countries of origin: Austria (n = 2), Brazil (n = 1), Bulgaria (n = 1), England (n = 1), France (n = 2), Italy (n = 1), Japan (n = 1), Mexico (n = 1), The Netherlands (n = 1), Norway (n = 24), Peru (n = 1), Poland (n = 1), United States (n = 3), and Uruguay (n = 1).

Table 2: *Overview of participants by courses and enrolled degree.*

course	*n*	enrolled degree		
		bachelor	master	PhD
1	16	0	16	0
2	7	7	0	0
3	6	4	2	0
4	8	0	5	3
5	4	0	2	2
total	41 (100%)	11 (26.8%)	25 (61%)	5 (12.2%)

3.2 Questionnaire

To measure science students' understanding of NOS, we applied the VNOS-D+ questionnaire from Lederman et al. (2010) via the online survey-system SurveyXact®. The questionnaire was administered once per course to examine the sample in the seven aspects of NOS (see table 1). Each student was given 60 minutes to complete the questionnaire. The instrument consists of 10 main open-ended questions that target specific aspects of NOS multiple times. For example, one prompt asks students in question 4b: "How certain are scientists about the way dinosaurs looked? Explain your answer." (Lederman et al., 2010, p. 4) targeting the aspects of tentativeness and inference (see table 1), another prompt asks students in question 8: "Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example." (Lederman et al., 2010, p. 6) targeting the aspect of theory and law (see table 1). The VNOS-D+ version is a shorter version of the VNOS-Questionnaire that provides almost the same data as the longer version VNOS-C. Due to its shorter length, VNOS-D+ may not fully encompass certain detailed or nuanced aspects that VNOS-C addresses. Consequently, the VNOS-C includes a greater number of questions, enabling a more comprehensive and in-depth examination of students' perspectives on NOS in a variety of scientific contexts (e.g., historical and sociocultural influences on science). The utilization of VNOS D+ represents a pragmatic and more efficacious methodology for the assessment of students' comprehension of the Nature of Science within a relatively brief period. In addition to the VNOS-D+, we collected socio-demographic data from each participant such as gender, enrolled degree, years of study and country of origin. The questionnaire was presented to the students in the original language (English). The students' answers were also given in English. The VNOS questionnaire is a widely used test instrument for the assessment of NOS comprehension in relation to the minimum consensus approach (e.g. Mesci, 2020; Narbona et al., 2023; Peters-Burton et al., 2019; Sevim & Pekbay, 2012; Wang et al., 2023; Wheeler et al., 2019). The validation process of the test instrument can be found in the original paper (see Lederman et al., 2010).

3.3 Data Analyses

Based on the recommendations from Lederman et al. (2010) we scored each student's views of the seven target aspects of NOS (see table 1). When coding, a numerical score was assigned to the participants' responses in each of the seven aspects, based on the standardized answer key ranging from a score of 0 to 3 (0 = Inadequate information to determine; 1 = Naïve responses are not consistent with any part of NOS aspect; 2 = Transitional responses are consistent with some, but not all, parts of NOS aspect; 3 = Informed responses are consistent and addresses all parts of NOS aspect). We conducted two rounds of coding using the answer key in consultation with all authors. The first author coded and analyzed the data and discussed responses that were difficult to score or unclear with the other authors until 100% consensus was reached. In table 3 coding examples of the responses can be seen. Coding was carried out in NVivo, version 12.

Once the data were evaluated, we first analyzed them by using descriptive statistical methods. Subsequently, statistical tests (Mann–Whitney U test & ANOVA) were used to analyze the differences between groups for gender, study program, country of origin and enrolled degree. For the total of the performed analyses, differences with $p<0.05$ were considered significant. Statistical tests were carried out in Jamovi, version 2.3.28.

Table 3: *Examples of coding of the responses to each aspect of NOS.*

Aspect	More naïve views	More informed views
Distinction between observations and inferences	"We can't go back in time, therefore they can't be sure because no one was there. They only can do sketches based on the fossils collected."	"Scientists don't have complete clarity on the subject, they can only rely on the evidence collected and the models that seem most convincing to them according to the fossil record they have."
Empirical	"Science is concerned with facts. We use observed facts to prove that theories are true." "Science deals with using an exact method."	"They need to find evidence against other solutions. Usually, it takes multiple lines of evidence coming together to convince scientists. It can't just be one reason, there usually needs to be corroborating evidence."
Creative and imaginative	"Scientist only uses imagination in collecting data. There is no creativity after data collection because the scientist is objective. "	"Logic plays a large role in the scientific process, but imagination and creativity are essential for the formulation of novel ideas [...] to explain why the results were observed."
Subjective	"Scientists are very objective because they follow clear rules and instructions to solve their problems."	"Scientists are human. They learn and think differently, just like all people do. They interpret the same data sets differently because of the way they learn and think, and because of their prior knowledge."
Social and culture embeddedness	"Science is about the facts and could not be influenced by cultures and society."	"[Science is pressured by culture,] I mean, the society and cultural values influence what topic the scientists work on. For example, the invention of medicine or vaccines."
Tentative	"Scientists try to prove theories empirically, so I don't think it can change."	"Yes, I believe that knowledge can change because as we discover new things the theories that are established now may turn out to be "wrong" because they don´t fit in with the new observations." "All theories have the potential to be changed upon new evidence which disproves or discredits the previous theory."
Distinction between scientific laws and theories	"A theory gives answers which permit to create laws. [...] A law is something proven to be true." "Laws started as theories and eventually became laws after repeated and proven demonstration."	"Theories set a framework of general explanation upon which specific hypotheses are developed. Theories [...] also advance the pool of knowledge by stimulating hypotheses and research." "A scientific theory is a theory that we (humans) construct to make sense of the natural world. It provides explanations and predictions of natural phenomena. A scientific law is a description of the uniformity of nature which we observe."

Finally, we compared our results with other studies that have used a VNOS form to investigate the understanding of NOS in science students. For a unified comparison, we used the unbiased pre-test results and assigned all non-evaluable answers, as far this information was given, to category 1, naïve (see table 3). The studies comparing the understanding of NOS were conducted at different times in different locations. The participants in the studies are similar, but not identical. They differ slightly in terms of fields of study, (future) professions and tenure.

4 Results

Most students have a transitional overall understanding of NOS ($\bar{x} = 2.02$). When examining the mean values, differences can be observed among each NOS aspect ($\bar{x}_{aspect1} = 2.49$, $\bar{x}_{aspect2} = 2.61$, $\bar{x}_{aspect3} = 2.68$, $\bar{x}_{aspect4} = 2.07$, $\bar{x}_{aspect5} = 2.61$, $\bar{x}_{aspect6} = 2.29$, $\bar{x}_{aspect7} = 1.39$). The mean values in the dataset range from 1.39 to 2.68. But the aspect of law and theory is striking. Unlike the other aspects, this aspect has a significant number of naïve answers ($\chi^2(3) = 18.22$, $p<.001$) and a mean value of 1.39 (see table 4). Disregarding this aspect, we find a reasonably homogeneous distribution of mean scores ranging from 2.07 to 2.68. All of the collected data have been categorized and assigned to the corresponding categories available (see table 3). In the overall assessment of the participants, none of the students was classified as naïve, 40 students were classified as transitional, and 1 student was classified as informed (see table 4). Considering the average mean value of all aspects rather than the overall assessment, a value of 2.30 is obtained. This not only affirms the overall evaluation result but also indicates a tendency toward transitional-informed perspectives.

According to a Mann-Whitney U test, we did not find significant differences in any of the seven NOS aspects between the students' professions in this study (see appendix 3). Furthermore, we did not find significant differences between groups based on gender, enrolled degree, course, and country of origin (see appendix 1, 2, 4, 5).

Comparing these results with other studies that have used a VNOS form to investigate the understanding of NOS in science students, we found that this cohort of Norwegian students have a better overall understanding of NOS (table 5). The proportion of informed students was higher in our group of students in every aspect except law and theory where we have similarly high number of naïve responses as the other studies (table 5).

Table 4: *Results of the evaluation of the students' views of NOS.*

		0 (inadequate)	**1 (naïve)**	**2 (transitional)**	**3 (informed)**	**Mean**
A1: Distinction between observations and inferences	n	1	0	13	27	2.61
	%	2.4	0	31.7	65.9	
A2: Empirical	n	3	4	4	30	2.49
	%	7.3	9.8	9.8	73.2	
A3: Creative and imaginative	n	2	2	3	34	2.68
	%	4.9	4.9	7.3	82.9	
A4: Subjective	n	9	3	5	24	2.07
	%	22	7.3	12.2	58.5	
A5: Tentative	n	0	1	14	26	2.61
	%	0	2.4	34.1	63.4	
A6: Social and culture embeddedness	n	5	6	2	28	2.29
	%	12.2	14.6	4.9	68.3	
A7: Distinction between scientific laws and theories	n	5	22	7	7	1.39
	%	12.2	53.7	17.1	17.1	
Overall evaluation	n	0	0	40	1	2.02
	%	0	0	97.6	2.4	

Note: 0 = Inadequate information to determine; 1 = Naïve responses are not consistent with any part of NOS aspect; 2 = Transitional responses are consistent with some, but not all, parts of NOS aspect; 3 = Informed responses are consistent and addresses all parts of NOS aspect.

***Table 5**. Comparison among studies measuring NOS in its seven aspects according to Lederman et al., 2010.*

Study	Participants	*n*	Method	N (1) T (2) I (3)	Empirical	Tentative	Observations/Inferences	Creativity	Subjective	Social-Cultural	Law and Theory
Norway (2024) Schaldach et al.	Graduate STEM-Students (incl. teaching program)	41	VNOS-D+ Questionnaire	1	17.1	2.4	2.4	9.8	29.3	26.8	65.9
				2	9.8	34.1	31.7	7.3	12.2	4.9	17.1
				3	73.2	63.4	65.9	82.9	58.5	68.3	17.1
Chile (2022) Narbona et al.	Graduate Students in Biology (prospective science teachers)	12	VNOS-D+ Questionnaire	1	8	0	42	0	33	8	
				2	0	50	8	83	25	42	
				3	92	50	50	17	42	50	
Portugal (2019) (Torres & Vasconcelos, 2020)	Graduate Students in Biology & Geology (prospective science teachers)	9	VNOS-C Questionnaire	1	55.6	77.8	77.8	66.7	33.3	44.4	100
				2	33.3	0	0	0	11.1	0	0
				3	11.1	22.2	22.2	33.3	66.7	55.6	0
USA (2018) (Wheeler et al., 2019)	Graduate STEM-Students	14	VNOS-C Questionnaire	1	0	23.1	7.7	15.4	23.1	15.4	38.5
				2	92.3	61.5	76.9	76.9	53.8	69.2	46.2
				3	7.7	15.4	15.4	7.7	23.1	15.4	15.4
Turkey (2018) (Kartal et al., 2018)	Science teachers	18	VNOS-C Interview	1	55	6	72	0	22	28	83
				2	39	78	22	61	50	6	11
				3	6	16	6	39	28	66	6
Turkey (2012) (Sevim & Pekbay, 2012)	Graduate Students (prospective elementary science teachers)	36	VNOS-C Questionnaire	1	0	70	86	33	81	75	94
				2	8	14	8	44	19	11	6
				3	92	17	6	22	0	14	0

Note: Values are given as percentages, N (1) = naïve, T (2) = transitional, I (3) = informed

0 – 20 %	20 – 40 %	40-60 %	60-80 %	80-100 %

5 Discussion

This study provides insights into science students' understanding of NOS in higher education in Norway and clarify the extent to which science students from the University of Bergen understand the concepts of NOS (RQ1) and to what extent the understanding of NOS differs from science students in other countries (RQ2). The analysis of the data collected from the VNOS-D+ shows that all participating science students demonstrated almost accurate or accurate views of NOS regardless of their gender, field of study, country of origin or academic degree. Although there have been many studies that have empirically tested the understanding of NOS, they have been mainly focusing on students' understanding at primary and secondary school levels and on pre-service and in-service teachers' education. In this study we investigated STEM-Students at universities, mainly biology majors, some with STEM teacher education.

In RQ1, we tested the understanding of NOS according to Lederman et al. (2010) with the VNOS-D+. Additionally, we collected further socio-demographic data to investigate group differences between the participants. The analyses show that all participating science students demonstrated almost accurate or accurate views of NOS in nearly every NOS aspect. Only the aspect of law and theory stands out for its prevailing naïve responses. In the overall assessment of NOS understanding, almost all students (97.5%) were assigned to the category transitional, which represents an understanding that is consistent with some, but not all, concepts of NOS. Furthermore, no differences in gender, field of study or academic degree were found in any of our analyses of group differences. Previous studies have shown contradictory results regarding the dependence of the study subject on NOS understanding. According to Akgun & Kaya (2020), Narbona et al. (2023) and Martin et al. (2007) results differ due to participants' majors. In contrast, Cavallo et al. (2003) found no significant differences between science and non-science majors.

We have collected data from STEM student teachers and biology students in higher education. Due to the strong overlap between the study programmes in our study, where teacher students and biology students take the same biology courses, it is not surprising that we were unable to identify any differences between those two groups. In contrast, studies such as Narbona et al. (2023) compare pre-service elementary teachers with pre-service biology teachers. These study programs differ significantly from one another in most countries (Cofré et al., 2015; Cofré et al., 2022; Narbona et al., 2023). The very similar study programmes in our study system also explain why we could not find any differences in the understanding of NOS between the different courses (see appendix 4). Previous studies have also shown that NOS understanding develops positively as a result of NOS-specific interventions (Kartal et al., 2018; Narbona et al., 2023; Pavez et al., 2016; Sevim & Pekbay, 2012; Wheeler et al., 2019). We expect the development of NOS understanding to continue in line with the course of the academic tenure. Therefore, we tested whether there were group differences between the responses of students enrolled in the bachelor's, master's, or PhD programmes. We could not detect any differences. This result might suggest that the students learn an adequate understanding of NOS during their first years at university,or even prior to that, based on their previous educational experiences. However, it must be borne in mind that the low number of participants in the bachelor's and PhD programmes in this study might have an impact on these results.

In RQ2, we compared our results with other studies that also used a VNOS form for their investigations, to investigate to what extent the understanding of NOS differs between science students from different countries.The participants among the studies are similar but not identical. They differ slightly in terms of study subjects, (future) professions and tenure. Norwegian students seemed to have a higher understanding of NOS than student from Chile (Narbona et al. 2022), Portugal (Torres & Vasconcelos 2020)), USA (Wheeler et al., 2019), and Turkey (Sevim & Pekbay 2012; Kartal et al., 2018). The high proportion of naïve answers to the law and theory aspect of NOS was similar between all countries. According to Schizas et al. (2016), the aspect of law and theory does not apply in all subject areas, making it meaningless in, e.g., biology. Lederman et al. (2014) argue that scientific laws and theories are inherently distinct, with laws capturing connections between observable phenomena and theories providing explanatory frameworks. It's worth considering whether these attempts to define the NOS across all natural sciences are shaped by the commonalities among these disciplines, as Lederman has focused on physics. Schizas et al. (2016) suggest that attempts to define NOS across all natural sciences are rhetorical. Therefore, the understanding of law and theory, as defined earlier, may not be relevant, especially in the context of biology.

Except for the clear trend in the aspect of law and theory towards naïve answers, the outcomes of each compared study vary among the different groups. Even when comparing our results with those of the most similar studies such as Wheeler et al. (2019) and Narbona et al. (2023), no consistent results can be found when comparing each single aspect of NOS. There might be many reasons for this, such as differently oriented courses during studies, different education systems or even differently shaped societies. In the present study, no difference was found between the answers from participants from different countries. However, it is unclear whether these students are only studying in Norway for a short time (e.g., in exchange programs) or long-term. Account must also be taken of the low representation in each given country. Nevertheless, these results give us an initial indication that NOS in science study programs in higher education is being taught to an appropriate degree.

In addition to the scoring of the seven aspects of NOS, an overall score of NOS understanding was also given to each participant (see table 4). This overall evaluation of NOS understanding is equivalent to the lowest score on the individual aspects, thereby reflecting the aspect where the participants demonstrated the least understanding. When calculated in this manner, the overall understanding of NOS in the present study is comparable to the studies summarized in table 5. Calculating the overall score as equal to the lowermost score leads to a loss of data from the VNOS questionnaire, eradicating the nuances and differences between the single aspects. On the other hand, the similarity in overall scores is in accordance with the results from the international comparison in the PISA study. PISA is collecting data about scientific literacy among 15-year-old pupils, including the ability to engage with science-related issues, and with the ideas of science, as a reflective citizen (OECD, 2019a; Teig, 2020). In the international ranking of the participating countries in PISA, Norway did not score significantly better than the average (OECD, 2019a, 2019b, 2023).

6 Limitations and implications

The students in this study chose to participate voluntarily and thus self-selected, which may introduce a bias towards students who already have knowledge about the subject. Furthermore, we used the VNOS-D+ despite criticism for insufficient contextualization and limited capacity to assess NOS in a more applied and scientifically literate manner (Allchin, 2011). Nevertheless, the VNOS questionnaire continues to have an important role in the NOS literature (Cofré et al., 2019). The questionnaire maintains a prominent position in NOS literature, and its continued widespread application is evident in recent studies by Mesci (2020), Peters-Burton et al. (2019), Wang et al. (2023), and Zion et al. (2020). Due to its standardized procedure and widespread use in current studies, we provide a rationale for the use of the test instrument despite the criticism. Moreover, the number of participants in this study must be considered when interpreting the results. The sample size does not allow generalizing conclusions to be drawn about all Norwegian science students. However, given the study design, the number of participants in comparable studies and the status of the University of Bergen as the third largest university in Norway, this study can be considered a meaningful case study. As part of future research projects, the results of this study should be compared with more data to determine whether the results correspond to a generalizable trend or whether they have occurred due to regional or university-related reasons. It may also be beneficial to delve deeper into the subject matter in subsequent studies. This would involve a more precise investigation of the level of NOS comprehension, as it appears that a ceiling effect may be occurring due to the selected questionnaire being either too coarse, unspecific or uncontextualized for the level of education typically attained in university. Furthermore, it might be interesting to assess which aspects of the students' education differ in comparison to other educational systems in order to design educational alternatives or adaptations of study programs for the purpose of an optimized understanding of NOS.

7 Conclusion

This study addresses a gap in the existing literature by examining the comprehension of the Nature of Science (NOS) among science students in higher education, specifically at the University of Bergen in Norway. The research aimed to present a comprehensive analysis of students' perspectives on NOS, both within the Norwegian context and in comparison, to international studies, using the Views of the Nature of Science - form D+ questionnaire. The findings of this study reveal that science students have an appropriate overall understanding of NOS, which is categorized as transitional, regardless of their study program, gender, academic tenure, or country of origin. Our results align with recent global studies, highlighting the influence of cultural and contextual factors on NOS understanding, as seen in the comparison with the studies from Wheeler et al. (2019) and Narbona et al. (2023). Despite limitations such as the voluntary and self-selected nature of participants and potential response bias, this study provides valuable insights into science students' understanding of NOS in higher education.

Statements and declarations

No funding was received for conducting this study. The authors declare they have no conflict of interest. All participating students gave their informed consent for inclusion before they participated in the study. The study was conducted in accordance with the Declaration of Helsinki. The Norwegian Agency for Shared Services in Education and Research (SIKT) approved the research procedures included in the project 511822.

PS: Conceptualization (equal), Data Curation (lead), Formal Analysis (lead), Investigation (lead), Methodology (lead), Project administration (lead), Resources, Validation (equal), Visualization (lead), Writing – Original Draft (lead), Writing – Review & Editing (lead). **RG**: Conceptualization (equal), Data Curation (supporting), Formal Analysis (supporting), Methodology (supporting), Supervision (supporting), Validation (equal), Writing – Review & Editing (supporting). **JN**: Conceptualization (equal), Data Curation (supporting), Formal Analysis (supporting), Methodology (supporting), Project administration (supporting), Supervision (lead), Validation (equal), Writing Review & Editing (supporting).

The authors confirm that the data supporting the findings of this study are available within the article.

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Appendices

Appendix 1: Independent Samples t-Test for gender

		Statistic	p
Distinction between observations and inferences	Mann-Whitney U	176	0.304
Empirical	Mann-Whitney U	171	0.208
Creative and imaginative	Mann-Whitney U	205	0.889
Subjective	Mann-Whitney U	192	0.627
Social and culture embeddedness	Mann-Whitney U	163	0.148
Tentative	Mann-Whitney U	187	0.494
Distinction between scientific laws and theories	Mann-Whitney U	142	0.057

Note: H_a $\mu_{female} \neq \mu_{male}$

Appendix 2: Independent Samples t-Test for study program

		Statistic	p
Distinction between observations and inferences	Mann-Whitney U	196	0.810
Empirical	Mann-Whitney U	197	0.825
Creative and imaginative	Mann-Whitney U	162	0.090
Subjective	Mann-Whitney U	199	0.893
Social and culture embeddedness	Mann-Whitney U	181	0.459
Tentative	Mann-Whitney U	192	0.705
Distinction between scientific laws and theories	Mann-Whitney U	186	0.612

Note: H_a $\mu_{Biologist} \neq \mu_{STEM\text{-}Teacher}$

Appendix 3: non-parametric ANOVA (Kruskal-Wallis test) for academic degree

	χ^2	df	p
Distinction between observations and inferences	0.0855	2	0.958
Empirical	0.1949	2	0.907
Creative and imaginative	3.1033	2	0.212
Subjective	0.5265	2	0.769
Social and culture embeddedness	2.4804	2	0.289
Tentative	0.7686	2	0.681
Distinction between scientific laws and theories	0.0388	2	0.981

Note: tested groups are Bachelor, Master, PhD

Appendix 4: non-parametric ANOVA (Kruskal-Wallis test) for course

	χ^2	df	p
Distinction between observations and inferences	4.534	4	0.339
Empirical	0.656	4	0.957
Creative and imaginative	4.864	4	0.302
Subjective	5.453	4	0.244
Social and culture embeddedness	2.227	4	0.694
Tentative	3.747	4	0.441
Distinction between scientific laws and theories	3.191	4	0.526

Note: tested groups are course 1, 2, 3, 4, 5

Appendix 5: non-parametric ANOVA (Kruskal-Wallis test) for country of origin

	χ^2	df	p
Distinction between observations and inferences	12.0	14	0.606
Empirical	21.1	14	0.100
Creative and imaginative	13.0	14	0.525
Subjective	18.4	14	0.190
Social and culture embeddedness	19.6	14	0.144
Tentative	15.0	14	0.380
Distinction between scientific laws and theories	14.5	14	0.411

Note: tested groups are Austria, Brazil, Bulgaria, England, France, Italy, Japan, Mexico, The Netherlands, Norway, Peru, Poland, United States, Uruguay