NOS Teacher Identity: A Case Study of Secondary Education Novice Science Teachers

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Abstract

The understanding of the Nature of Science (NOS) is crucial in developing scientific literacy, a fundamental goal of science education. Scientific literacy extends beyond mere knowledge; it encompasses an understanding of science's methodologies, cultural and social influences, and the evolving nature of scientific knowledge. In this context, the professional identity of teachers, who not only grasp NOS concepts but can also effectively impart this understanding, becomes critical. This study explores the interplay between science teacher identity and their understanding of NOS, emphasizing the importance of targeted NOS instruction in teacher education programs. We conducted a qualitative case study with five novice teachers, each with less than five years of professional experience, using a questionnaire based on NSTA recommendations related to NOS. Employing Atlas.ti software (v 23.3.0) for analysis, we identified 26 codes related to aspects such as the reliability and changeability of scientific knowledge (e.g., theory revision and adaptation, predictive nature of theories) and the naturalistic methods and explanations in science (e.g., explanation of natural phenomena, interrelation of facts, laws, and theories). The results reveal a robust foundation in key NOS aspects, particularly in recognizing the empirical nature of science and its human dimensions. However, a lesser emphasis on the adaptability and revisability of scientific knowledge was observed. This suggests a need for deeper engagement with the concept of the dynamic nature of scientific understanding. Enhancing the novice teachers' grasp of areas such as the evolving nature of scientific knowledge and critical analysis will further solidify their NOS teacher identity, equipping them to deliver a more comprehensive and nuanced science education.

Keywords: *teacher identity, NOS identity, scientific literacy, qualitative analysis*

1. Introduction

The understanding of the Nature of Science (NOS) is integral to developing scientific literacy, a key outcome of science education. This literacy encompasses not just scientific knowledge but also an understanding of how science operates, including its methodologies, cultural and social influences, and the tentativeness of scientific knowledge. Conceptualized as the professional teachers' identity who not only understand NOS but are also equipped to effectively teach it [1], NOS identity is an amalgamation of personal beliefs, professional knowledge, and the ability to impart NOS understanding to others, including also previous exposure to science and science education, as well as the intrinsic value and understanding of the NOS [2]. Regarding this highly-dependant contextual background, factors such as support from peers and mentors, professional development opportunities, and the educational environment significantly impact the development of a NOS identity [3], and consequently, supportive environments can facilitate this development, whereas unsupportive contexts may hinder it. On the other hand [4], also highlight the role of cultural experiences and intersectionality in shaping science teacher identity. This perspective acknowledges that cultural practices and race significantly influence how educators perceive and integrate NOS into their teaching.

1.2 Significance of NOS Identity

The complex interplay of personal experiences, cultural influences, and professional training on defining NOS identity framework, shapes how teachers approach to teaching NOS, which is particularly relevant in the context of pre-service teacher training, where the development of a strong NOS identity is essential. It underscores the need for teacher training programs to incorporate explicit and reflective NOS instruction, considering diverse cultural and personal backgrounds of trainees [2].

Accordingly, for pre-service secondary education science teachers, developing a NOS identity is crucial as it directly impacts their future role in fostering scientific literacy among their students.

Since there is a relationship between science identity and understanding of the NOS [5], its conceptualization significantly influences individuals' perceptions about who can be considered a scientist and who is permitted to participate in scientific endeavours. By adopting a subjective and diverse view of NOS, traditional stereotypes about scientists (typically perceived as white males) can be challenged. This broader and more inclusive perspective on NOS, which acknowledges its social and cultural dimensions, helps individuals develop a science identity and, more specifically, a NOS identity. This shift is crucial for diversifying the field of science and changing long-standing perceptions about who engages in scientific work. Consequently, targeting NOS instruction in teacher education programs, recognising the diverse backgrounds of pre-service teachers, plays a pivotal role.

Considering the importance of developing the NOS teacher identity, the primary goal of this research is to examine the depth of understanding and application of the NOS among novice science teachers (recently graduated from the master's degree in Physics and Chemistry Secondary Education [MEd], and with less than five years of professional experience), focusing on how effectively they can communicate these concepts within educational settings. By doing so, this study aims to bridge the gap between theoretical knowledge of NOS principles and practical teaching skills that enhance scientific literacy among students, offering an outlook to the following research questions:

- How do novice science teachers understand the various aspects of the NOS?
- What are the strengths and weaknesses in the NOS teacher identity as reflected in their responses to the NOS-oriented questionnaire?

2. Methodology

Five novice teachers participated in this study held at the University of Málaga, all of them enrolled in the MEd, a prerequisite for teaching in secondary schools in Spain. All of them received a specific training on inquiry-based science education during their pre-service teachers' training [6].

Data were collected through a structured questionnaire during academic year 2020/2021 in a voluntarily base, following the protocol stablished by the Ethics Committee (CEUMA) (reference no. 113-2021-H). For the design of the questionnaire, we adapted the Teachers' Pedagogical Philosophy Interview (TPPI) [7], by selecting the ten questions related to NOS (table 1). We then proceeded to analyse participants responses following the National Science Teacher Association [NSTA] framework about the concepts related to NOS [8] (NSTA, 2020), that synthesise them in eight main categories such as the conceptualization of science as a way of knowing or the variety of methods used in scientific investigations (table 1). We performed a qualitative analysis of the responses through a categorisation process using ATLAS.ti software (version 24.1.0). Both co-authors completed the reading and coding independently [9] and guaranteed the confidentiality of the data, which was reinforced by subsequent discussions and consensus agreements.

Table 1. Items of the questionnaire and their relationship to NOS dimensions

Questions	NOS dimensions (NSTA)
Q1 What are facts, laws and theories in science? **Q2** How are facts arrived at? **Q3** How do you distinguish among facts, laws, and theories in science? **Q4** What is science? **Q5** In what ways do you learn science best? **Q6** When you learn science, is it different than learning other subjects? **Q7** What are the founding principles of science? **Q8** What are some of the things you value most about science? **Q9** What science concepts do you believe are the most important for your students to understand by the end of the school year? **Q10** How do you want your students to view science by the end of the school year?	**NOS1 Scientific investigations use a variety of methods** *Discussion about facts, laws and theories in science, emphasising the variety of methods used in scientific investigations*
	NOS2 Scientific knowledge is based on empirical evidence *Discussion about reaching scientific facts, highlighting the importance of empirical evidence in the foundation of scientific knowledge*
	NOS3 Scientific knowledge is open to revision in light of new evidence *Insights on distinguishing between facts, laws, and theories, and how they are open to revision with new evidence*
	NOS4 Science models, laws, mechanisms, and theories explain natural phenomena *Participants' personal views on science, relating to how scientific models and theories explain natural phenomena*
	NOS5 Science is a way of knowing *Discussion about the best ways to learn science, reflecting on science as a way of knowing*
	NOS6 Scientific knowledge assumes an order and consistency in natural systems *Perspective on how learning science is different from other subjects, indicating and understanding of the order and consistency in natural systems*
	NOS7 Science is a human endeavour *Description of fundamental principles of science, highlighting the human aspect of scientific endeavour*
	NOS8 Science addresses questions about the natural and material world *Discussion about values, showing how science addresses broad questions about the natural and material world*

3. Results and Discussion

Table 2 describes de 26 codes categorized into the eight NOS dimensions recommended by NSTA, and the frequence and relative percentage for each code, providing a rich view of the novice teachers' understanding and emphasis on different aspects of science education.

Table 2. NOS dimensions and factor categories

Dimension and codes	Frequency	%
NOS1 - Scientific investigations use a variety of methods		
Observation and rational explanation	6	26.1
Observations leading to scientific explanations	3	13.0
Hypothesis formation and testing	3	13.0
Observable and testable events	5	21.7
Reproducible actions	6	26.1
TOTAL	**23**	**100.0**
NOS2 - Scientific knowledge is based on empirical evidence		
Repeated observations	1	16.7
Isolated observations	1	16.7
Natural observation and laboratory experimentation	2	33.3
Observable and experienced-based	2	33.3
TOTAL	**6**	**100.0**
NOS3 - Scientific knowledge is open to revision in light of new evidence		
Predictive nature of theories	1	20.0
Theoretical frameworks supporting laws	3	60.0
Integration of new evidence	1	20.0
TOTAL	**5**	**100.0**
NOS4 - Science models, laws, mechanisms, and theories explain natural phenomena		
Explanation of natural phenomena	4	57.1
Theoretical models and representation	2	28.6

Application of scientific laws		1	14.3
	TOTAL	**7**	**100.0**
NOS5 - Science is a way of knowing			
Empirical understanding of the world		3	33.3
Rational explanation and reasoning		2	22.2
Integration of knowledge		2	22.2
Critical thinking and analysis		2	22.2
	TOTAL	**9**	**100.0**
NOS6 - Scientific knowledge assumes an order and consistency in natural systems			
Order and systematic approach		3	75.0
Structured inquiry and investigation		1	25.0
	TOTAL	**4**	**100.0**
NOS7 - Science is a human endeavour			
Human influence and perspective		2	33.3
Cultural and social influence on science		1	16.7
Personal and collective endeavour		2	33.3
Ethical and moral considerations		1	16.7
	TOTAL	**6**	**100.0**
NOS8 - Science addresses questions about the natural and material world			
Real-world applications and relevance		5	100.0
	TOTAL	**5**	**100.0**

One of the most notable strengths is the emphasis on empirical aspects of science, as stated by the high frequency of codes such as "Observation and rational explanation" and "Reproducible Actions," each scoring 26.1% in the NOS1 dimension, indicating a robust understanding that scientific inquiry is grounded in observable, verifiable events. Similarly, the "Empirical understanding of the world" within the NOS5 dimension resonates well, highlighting a solid grasp of how empirical data forms the backbone of scientific knowledge.

Additionally, there's a significant focus on applying scientific knowledge to real-world scenarios, as seen in the NOS8 dimension, where "Real-world applications and relevance" accounts for 100% of the responses. This underscores a practical approach to science teaching, emphasizing how scientific concepts are not just theoretical but have tangible implications and applications in everyday life.

However, there are notable gaps that suggest areas for improvement. A glaring concern is the complete absence of responses in several critical categories. For instance, in the NOS3 dimension there were no instances of theory revision and adaptation, which might indicate a need for more emphasis or understanding of scientific theories' dynamic. Comprehension of this ever-evolving nature is crucial for fostering a flexible and inquisitive scientific mindset among students.

Similarly, there is no mention to interrelation of facts, laws, and theories within the NOS4 dimension, suggesting a potential weakness in connecting different scientific ideas and concepts, which is essential for students to develop a holistic understanding of science.

Finally, in the NOS6 dimension, there is also an absence related to the consistency and predictability in nature or universal laws and principles, which could point to an underappreciation of the fundamental order and predictability that govern natural phenomena—a core aspect of scientific literacy.

4. Conclusions and Educational Implications

Analysing the responses from the pre-service teachers in the context of the NSTA's NOS dimmensions reveals a multifaceted understanding of scientific concepts and processes, indicative of their emerging NOS teacher identity. A significant strength identified in their responses is the emphasis on empirical evidence and the application of scientific methods. The participants consistently highlighted the importance of observable, testable events and empirical data, demonstrating a solid foundation in the practical aspects of science teaching. This emphasis is crucial in science education as it fosters a hands-on, inquiry-based approach to learning, encouraging students to engage directly with scientific phenomena.

However, an area that appears to be less emphasized and could be considered a relative weakness is the adaptability and revisability of scientific knowledge. While there is some recognition of the dynamic nature of science, the responses suggest a need for a deeper engagement with the idea that scientific understanding evolves over time. This aspect is essential in developing a complete NOS teacher identity, as it helps students appreciate the provisional nature of scientific knowledge and the ongoing process of scientific inquiry.

Another key strength in their responses is acknowledging science as a human endeavour. This reflects an understanding that science is influenced by human perspectives, cultures, and social contexts. This recognition is vital for making science education more inclusive and relevant to diverse student populations.

On the other hand, there appears to be less focus on the critical thinking and analysis aspect of science as a way of knowing. Strengthening this area could further enhance their ability to teach students how to think like scientists, evaluating evidence critically and making reasoned conclusions.

Overall, these novice teachers demonstrate a solid foundation in several key aspects of the NOS, particularly regarding the empirical nature of science and its human dimensions. Continuing to develop their understanding and teaching approaches in areas like the evolving nature of scientific knowledge and critical analysis will further strengthen their NOS teacher identity, enabling them to provide a more comprehensive and nuanced science education.

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