

## LINKING NATURE OF SCIENCE UNDERSTANDING TO MODELING-DRIVEN INSTRUCTION: EVIDENCE FROM QUANTITATIVE EDUCATIONAL ANALYSIS

H. Seghir<sup>1,2</sup> M. Serghini<sup>1</sup> N. Boucetta<sup>3</sup> S. Boubih<sup>3</sup> A. Ouhtit<sup>2</sup> G. Ghariz<sup>2</sup>  
Y. Ou Sekou<sup>1</sup>

1. Mathematics, Informatics, and Pedagogical Engineering Team, Mathematical and Informatics Modeling Laboratory, Higher Normal School, Moulay Ismail University, Meknes, Morocco  
*h.seghir@umi.ac.ma, m.serghini@umi.ac.ma, y.ousekou@umi.ac.ma*
2. Research Team in Pedagogical Engineering and Science Education, Higher Normal School, Abdelmalek Essaadi University, Tetouan, Morocco, *abdelkader.ouhtit@etu.uae.ac.ma, gharizghizlane@gmail.com*
3. Institute of Nursing Professions and Health Techniques, Tetouan, Morocco  
*boucettanajat1970@gmail.com, said.boubih@etu.uae.ac.ma*

**Abstract-** Having a firm grasp of the nature of science (NOS), which guides the modelling and analysis of biological systems, is crucial for scientific literacy and mastery of scientific knowledge. Teachers' conceptions of NOS are essential for guiding effective strategies such as the formulation, modelling, and teaching of biological problems in life and Earth science classrooms. In this study, the opinions of 140 Moroccan teachers of life and earth sciences on the nature of science are explored in conjunction with teaching methods involving the modelling of biological problems. To study the relationships between teachers' understanding of the nature of science and their strategies focused on modelling, such as inquiry-based learning, collaborative problem solving, and problematization of biological systems, data were compiled through a structured questionnaire and examined statistically. The results demonstrate the impact of epistemological knowledge on pedagogical decision-making by showing a strong correlation among teachers' beliefs of NOS and their pedagogical and instructional strategies for simulating biological processes. To enhance the teaching strategies and learning process of biological systems, these outcomes of this study highlight the importance of integrating NOS into teacher training programmes. Further research, particularly qualitative studies, is recommended to examine the mechanisms that link teachers' methods of modelling biological problems to their epistemological conceptions.

**Keywords:** Nature of Science, Modelling Biological Problems, Life and Earth Sciences, Instructional Strategies, Moroccan Teachers.

### 1. INTRODUCTION

The fundamental purpose of science education is to ensure that every student is scientifically literate. Scientific

literacy incorporates understanding not only scientific knowledge but also scientific processes and their nature - what science is and how scientists work and the practices used in Scientific Inquiry SI. This knowledge is crucial for motivating students to formulate, model, and analyze biological systems and problems in Life and Earth Sciences LES. Therefore, in order to model scientific thinking and choose instructional strategies that mirror Real-world scientific practices and facilitate the modeling of biological phenomena, teachers must have well-developed notion of NOS [1].

Unfortunately, research shows that most teachers around the world have a limited understanding of NOS [2]. The NOS has been a fundamental goal for major science education reform efforts around the world [3-4]. Despite research into the Nature of Science NOS, they enjoy increasing international attention [5]. The Nature of Science NOS research in Middle Eastern and North African (MENA) countries is largely neglected. Hence, the importance of conducting this research in Morocco [6-7]. In the Moroccan educational context, constraints such as inadequate teaching strategies and limited opportunities for professional development continue to hinder the effective teaching of scientific research, problem solving and modelling of biological systems, as reflected in the results of national and international assessments.

This research investigates LES teachers' conceptions of the Nature of Science NOS and science teaching. Consequently, the research aims to examine the relationship between teachers' perception of the Nature of Science NOS and teaching strategies. If conceptual understanding the NOS has a causal impact on the choice of classroom activities, we must find a correlation between our measures of comprehension the NOS, on the hand, and our measures of science teaching strategies, on the other. More specifically, the study aims to:

1. Identify teachers' conceptions of NOS
2. Analyze their vision of science teaching as a process involving research, modelling and the formulation of biological problems
3. Examine the relationship between teachers' comprehension of NOS and their pedagogical choices and instructional strategies, including collaborative work, inquiry-based learning, and problematization of biological systems.

The hypothesis is that teachers' understanding of NOS positively influences their adoption of pedagogical strategies that promote modelling and analysis of biological phenomena. By addressing these objectives, this study contributes to a better comprehension of the role of teachers' epistemological knowledge in the development of modelling-based teaching practices in LES. The results aim to inform teacher training and professional development programmes by emphasizing the integration of NOS and biological problem modelling as key components of effective science teaching in Morocco.

## **2. THEORETICAL FRAMEWORK**

### **2.1. The Nature of Science (NOS) and Epistemology**

The concept of the NOS refers to the epistemology and science as a means of knowledge, or to the values and beliefs essential in the progression and evolution of scientific knowledge [8]. Although there is no universal definition due to the complexity and dynamism of science, but there are generalities that science teachers, in general, should understand in order to convey them to their students. According to the contemporary epistemology of science, characterizes science as [8]:

- ❖ Refutable, provisional and uncertain: science is evolving, moving, and unstable [9-10].
- ❖ Socially and culturally influenced and embedded: science interacts with the different components of society and progresses according to the evolution of society [11].
- ❖ Partially empirical and experimental: to solve a problem, or to verify a hypothesis, there is a multitude of scientific approaches, such as, surveys by questionnaire, interviews, observations of people and facts in society...Given that scientific approaches are multiple [11-12].
- ❖ Partially subjective: scientific work can be influenced by the theoretical and disciplinary knowledge, beliefs, conceptions, experiences, personal choices and expectations of the researchers, and more specifically the choice of the problems to be investigated, the methods of investigation, the collection of data and their interpretations, which diminishes the objective character of their work [13].
- ❖ It depends in part on human creativity and imagination: science implies the invention of explanations and scientific models, which requires a good dose of creativity and imagination on the part of scientific researchers [14].

### **2.2. Scientific Inquiry SI as a Pedagogical Approach**

Scientific inquiry (SI) is not a simple process that aims only to develop procedural skills such as observation,

deduction, classification, prediction, measurement, questioning, interpretation and data analysis. Scientific inquiry (SI) includes traditional scientific processes but also refers to the combination of these processes with scientific knowledge to develop a solid scientific knowledge base [15]. Inquiry-based learning encourages students to:

- Ask questions and formulate hypotheses
- Design investigations and analyse data
- Communicate results effectively

This approach promotes mastery of scientific concepts, critical thinking, problem solving and scientific literacy, providing students with authentic, meaningful and stimulating learning experiences.

### **2.3. Role of Epistemology in Science Teaching**

Epistemology and science didactics are intimately linked; science epistemology enables us to analyze and question scholarly knowledge. As such, it is omnipresent in the conceptions of teachers and students. Consequently, it is essential to consider the epistemological dimensions of science in teaching strategies and learning processes. In traditional education, science is often presented in a truncated manner, neglecting certain aspects, particularly historical and epistemological dimensions. Science is assumed to be based solely on observation, experimentation, and logical reasoning, following a predetermined sequence of steps.

As a result, the science taught in this manner becomes rigid, reductionist, even dogmatic, and devoid of its human dimension. This type of science is also unappealing, failing to ignite the student's imagination and enthusiasm. That is why it is timely to reintroduce historical and epistemological aspects into science education, as they open new horizons and present multiple utilities.

### **2.4. Modelling and Epistemological Conceptions**

In this study, modelling is conceptualized as a structured epistemological process that enables the representation, analysis, and interpretation of scientific and instructional systems. From an engineering-informed perspective, modelling is defined through three complementary forms: conceptual modelling, mathematical/statistical modelling, and simulation-based modelling. Conceptual modelling supports inquiry-based instruction by facilitating problematization, system abstraction, and the identification of key variables and relationships. Mathematical and statistical modelling enables the quantitative analysis of epistemological parameters and, allowing for sensitivity analysis and parameter differentiation. Simulation-based modelling supports predictive reasoning and iterative refinement through feedback loops, which are essential for optimizing instructional strategies.

These modelling forms are closely linked to teachers' epistemological understanding of the Nature of Science (NOS), as epistemic awareness guides the selection, construction, and validation of models in both scientific inquiry and instructional design. In this framework, teachers' NOS conceptions function as epistemological

inputs that shape modelling-driven instructional processes and influence learning outcomes. A summary of the relationships between modelling types, instructional functions, and analytical benefits is presented in Table 1, which provides a structured overview of the proposed modelling hierarchy.

Table 1. Types of modelling, instructional functions, and analytical benefits

Modeling Type	Instructional Function	Analytical benefits
Conceptual modelling	Problematization and inquiry framing	System abstraction and variable identification
Mathematical / statistical modelling	Evidence-based instruction and assessment	Sensitivity analysis and parameter differentiation
Simulation-based modelling	Prediction and iterative learning	Feedback loops and instructional optimization

### 3. MATERIALS AND METHODS

#### 3.1. Research Problem

In this study, we address a critical issue for the development of 21st-century scientific literacy, namely the role of teachers' conceptions of the Nature of Science (NOS) as key input parameters influencing instructional design and learning outcomes. From an engineering-oriented perspective, teachers' epistemological conceptions can be considered as system-level variables that shape pedagogical modeling strategies and determine the extent to which scientific knowledge becomes transferable to diverse real-life contexts.

In recent years, the Moroccan Ministry of Education has revised school curricula by allocating increased instructional time to science education [16]. This reform aims to enhance students' awareness of the societal value of science and to engage them in learning environments that simulate scientific practices and reasoning processes [17]. Such curricular orientations implicitly require teachers to adopt model-based and inquiry-oriented instructional approaches, grounded in an informed understanding of NOS.

Within the Life and Earth Sciences (LES) program, teachers' understanding of NOS constitutes a core structural component of the instructional system, as it directly affects how scientific concepts, methods, and uncertainties are represented to learners. A well-developed conception of NOS supports students' construction of a coherent scientific culture, enabling them to interpret evidence, reason scientifically, and make informed decisions [8].

However, the effective development of this scientific culture through LES teaching strategies depends on the interaction of multiple subsystems, including epistemological beliefs, didactic choices, pedagogical practices, and disciplinary content knowledge. This interaction also encompasses an understanding of the historical development and evolution of biological and geological sciences, which informs how models, explanations, and scientific knowledge are constructed and revised over time [16].

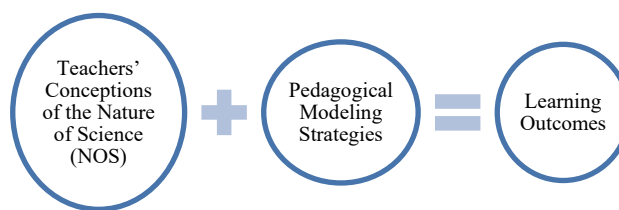


Figure 1. Conceptual system model linking teachers' conceptions of the Nature of Science (NOS), pedagogical modelling strategies, and learning outcomes in Life and Earth Sciences education [8], [16]

Figure 1 shows a systemic relationship in which teachers' conceptions of the nature of science (NOS) act as epistemological inputs that influence pedagogical strategies for modelling and problem solving, and consequently, learning outcomes in terms of scientific literacy, the transferability of scientific knowledge, and decision-making skills. From a system-analysis standpoint, this research conceptualizes teachers' conceptions of NOS as inputs, instructional strategies as processes, and teaching effectiveness indicators as outputs. The study seeks to examine how variations in epistemological inputs propagate through pedagogical modelling processes and influence observable teaching practices. Accordingly, the research addresses the following questions and associated hypotheses:

- RQ1: What are Life and Earth Sciences teachers' conceptions of the NOS?  
H1: Teachers' perception of NOS is heterogeneous, sometimes aligning with contemporary epistemological paradigms and sometimes diverging from them.
- RQ2: What are Life and Earth Sciences teachers' conceptions of science teaching?  
H2: Teachers' views on science teaching exhibit a degree of heterogeneity.
- RQ3: Is there a relationship between Life and Earth Sciences teachers' conceptions of NOS and their teaching strategies?  
H3: There is a correlation between teachers' comprehension of NOS and their science teaching practices and strategies.

#### 3.2. Participants

A total of 140 professionals in Life and Earth Sciences education participated in this study, including 53.6% female and 46.4% male participants, drawn from various public institutions across Morocco (Figure 2). Among them, 55% are practicing teachers, 33.6% are teacher trainees, 3.6% are trainers in training centers, and 7.9% are pedagogical inspectors in secondary education. Concerning continuing professional development, 62.6% of the participants reported not having received any training related to epistemology or the history of sciences, whereas 37.4% indicated that they had undergone training in these areas (Figure 3).

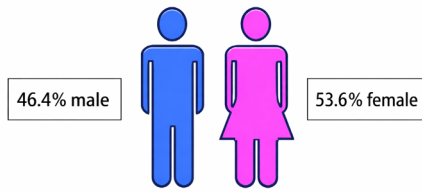


Figure 2. Percentage of participants by gender

have you received training in epistemology?

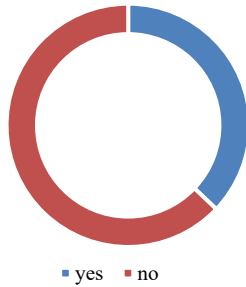


Figure 3. Distribution of teachers with and without training in epistemology (%)

3.2. Material

The study employed a three-part questionnaire. In the first part, participants provided personal and professional information, including age, gender, years of experience, position, academic background, and the regional academy in which they are employed. The second part assessed participants’ beliefs of the NOS through 24 statements assessed on a five-point Likert scale. These 24 items were organized into eight themes, each comprising three items (Table 2).

Within each theme, the first two items had direct valence and were scored according to the standard Likert scale (1 = “strongly disagree,” 2 = “disagree,” 3 = “neither agree nor disagree,” 4 = “agree,” 5 = “strongly agree”). The third item in each theme had an inverted valence and was reverse scoring (1 = “strongly agree” to 5 = “strongly disagree”). Thus, agreement with a theme was determined through a combination of “agree” and “disagree” responses across its three items. The third part of the questionnaire focused on participants’ views on science teaching. Items were grouped into themes addressing the aims of science teaching, teaching methodology, as well as challenges and opportunities for improvement. Responses were also rated on a five-point Likert scale (Table 3).

Table 2. Themes and items related to the nature of science, as well as the average values and standard deviation for each theme and items

Items	Mean values	Standard deviation
Theory support	3.91	0.78
scientific theories are not mere assumptions	3.80	1.19
For theories to be acceptable, they must be supported by solid evidence.	4.29	1.09
-New hypotheses are essentially risky conjectures; scientists just simply imagine them <sup>a</sup>	3.65	1.22
The limits of science	3.60	0.67
Theories can explain phenomena but are incapable of proving them	3.56	1.23
Accepted scientific theories that can explain several phenomena	3.59	1.10

Theories are essentially instinct; they have not yet gathered sufficient corroborating evidence to be considered hypotheses <sup>a</sup>	3.65	1.09
Theory and hypothesis testing	3.81	0.71
Tests are the foundation of science, so hypotheses can be tested in different methods.	4.00	0.99
The same hypothesis or theory can be tested using various methods.	4.05	0.99
Research in science advances solely through laboratory experiments	3.39	1.33
Linearity, or non-linearity of scientific processes	3.88	0.84
The process of research in science is non-linear. dynamic and context-dependent	3.76	1.22
The process of research in science is non-linear; each step can lead to several possible subsequent steps.	3.92	1.19
Researchers systematically follow the same step-by-step of the scientific method like a ready-made recipe	3.96	1.02
Theory building	3.48	0.65
Theory is produced; they are not simply an interpretation of nature phenomena.	2.89	1.24
Scientific knowledge is acquired through a complex process that can be based on the observation of nature.	3.89	1.04
- scientific knowledge is derived directly from observations of nature	3.66	1.11
Creativity and imagination in science	3.62	0.93
Science draws on imagination and innovation.	3.53	1.22
Researchers often use their imagination and innovation when designing new experiments, hypotheses and theory.	3.61	1.21
Imagination and creativity influence researchers' objectivity. which is why scientists do not resort to their imaginations and innovation	3.73	1.06
Scientific community	4.10	0.72
In the scientific field, the scientific community plays a crucial role.	4.22	0.97
The advancement of science depends on the important role played by the scientific community.	4.11	1.03
science is almost always an individual activity	3.96	0.88
Society and culture (whether or not they influence science)	3.52	1.10
Social and cultural factors influence science	3.56	1.28
Individual scientists are influenced by their societies and cultures, which in turn, influence their practice.	3.59	1.19
Science is not influenced by society or culture because scientists work in a neutral and objective manner	3.42	1.32

<sup>a</sup> indicates items that were reverse scoring to generate the theme average

Table 3. Science education themes with sample items and mean values for each theme and item, followed by standard deviation

Items	Mean values	Standard deviation
Aims of science teaching	3.34	0.42
Getting students to work as researchers in investigative situations	4.19	0.99
Preparing students for the 21st century	3.61	1.17
- Building scientific concepts for reuse in life	4.13	0.96
- Preparing students for higher education	2.29	1.16
- Transmitting scientific knowledge	2.49	1.26
Difficulties in science teaching	3.62	0.49
- Lack of historical data on scientific concepts taught in the SVT curriculum (history of the concept of natural selection)	3.51	1.25
- Limited knowledge and lack of training for teachers in the didactics, history and epistemology of science	3.60	1.12
- Insufficient time volume / program and class overloads	4.30	0.98
- Students' lack of motivation for scientific subjects	2.26	1.22
- I don't think there are any difficulties in teaching science. <sup>a</sup>	4.43	0.79

Science teaching methodology	3.34	0.42
Use active approaches such as the investigative approach to reconstruct scientific concepts	4.24	0.95
Getting students to work in groups by encouraging class debate	4.14	0.94
Present and explain scientific ideas to the whole class	3.10	1.24
Have students work individually on exercises or tasks at the same pace	3.44	1.23
Building upon students' initial conceptions by offering problematizing situations	1.77	0.89
Improving science teaching	3.60	0.61
- Integration of the history and epistemology of science in initial and continuing teacher training	3.98	1.04
Encouraging students to work together on an interdisciplinary project	4.16	0.93
Researching practical and concrete solutions to promote the development of skills in science classrooms.	4.16	0.98
Explanation and re-explanation of scientific concepts	2.72	1.23
- Schedule support hours to repeat course explanations	3.00	1.36

<sup>a</sup> indicates items that were reverse scoring to generate the theme average

Many of the items and themes were adapted from previous studies [18-19], and modified to align with the objectives and context of the present study. The questionnaire design steps shown in Figure 4.

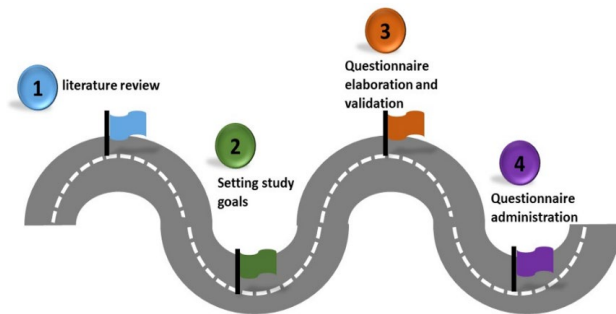


Figure 4. Questionnaire design steps. Source: the work of Liang and Lombroso with modifications

### 3.3. Procedure

The questionnaire was developed using Google Forms and was available from January 15 to the end of March 2023. It was distributed digitally through multiple channels, including WhatsApp and Facebook groups dedicated to Life and Earth Sciences teachers. Additionally, it was sent via email to pedagogical inspectors and teacher trainees undergoing professional training at the Regional Centers for Education and Training Professions in Tangier, Casablanca, and Marrakech. This distribution strategy allowed the questionnaire to be administered without direct contact with participants. The extended response period facilitated the collection of a satisfactory number of responses.

### 3.4. Coding

Each set of items in each theme included items with direct valence, which were coded according to the standard Likert scale. Responses on a scale from 1 ("strongly disagree") to 5 ("strongly agree"). Regarding statements marked with an asterisk in Tables 1 and 2, indicating a reversed valence where responses expressing disagreement contribute to the approval of the theme,

values were coded in the opposite direction: on this scale, 1 represents high level agreement, whereas 5 represents high level of disagreement.

### 3.4. Data analysis

To answer our study questions and test our hypotheses, we carried out several statistical analyses on the data collected. First, we calculated means and standard deviations for all questionnaire items by using Equations (1) and (2):

$$\text{Mean} = \frac{\sum_{i=1}^5 \text{Likert Scale}_i \times \text{Number of respondents}_i}{\text{Number of respondents}} \quad (1)$$

$$\text{Standar deviation} = \sqrt{\frac{\sum_{i=1}^5 (\text{Number of respondents}_i) \times (\text{Likert}_i \times \text{Mean})^2}{\text{Number of respondents} - 1}} \quad (2)$$

These measures gave us an overall view of participants' responses. Regarding inferential statistics, bivariate correlation analysis was employed to examine linear relationships among the NOS and its eight thematic dimensions, with correlation coefficients interpreted as indicators of system sensitivity to epistemological parameters. In addition, bivariate ANOVA was used as a parameter differentiation mechanism to assess how variations in respondents' professional characteristics (e.g., educational position and years of experience) produce statistically distinct effects on the overall NOS score. These analyses support the identification of influential input variables relevant to instructional modelling and intervention design. All statistical procedures were performed using SPSS software (version 20.0), a widely adopted tool in scientific research.

## 4. RESULT AND DISCUSSION

For each of the questions posed, we will successively present the results and analyses concerning their conceptions of the nature of science (RQ1), then those concerning their conceptions of science teaching (RQ2), and finally the link between representations of the NOS and science teaching (didactic and pedagogical choices) (RQ3).

### 4.1. Teachers' Beliefs of the NOS

To evaluate teachers' conceptions of the nature of science, mean values and standard deviations were calculated for respondents' answers to 24 statements grouped under eight thematic areas (Table 1). Following Le Poulter's (1986) categorization, as cited by [20-21], mean scores were classified into three levels of approval: low (1-2.33), moderate (2.34-3.67), and high (3.68-5).

Overall, results predominantly fell within the moderate to high categories, with low standard deviations, indicating a positive consensus among teachers on NOS themes. When ranked from highest to lowest averages, significant trends emerge. At forefront of themes receiving strong approval from respondents is theme 7: Scientific Community, with an impressive mean value ( $M=4.10$ ). This finding suggests that teachers place significant importance on the scientific community in the context of

science, acknowledging its crucial role in the scientific process and the advancement of the discipline.

- Theme 1: Support for Theory closely follows with a significant mean value ( $M=3.91$ ), indicating strong support for scientific theories, emphasizing the need for substantial evidence to support them. This positive perception suggests a solid understanding of how theories are constructed and supported in the scientific context.

- Theme 4: Linearity or non-linearity of scientific processes follows with a mean value ( $M=3.88$ ), demonstrating that teachers recognize the non-linear, complex, and contingent nature of the scientific process. They seem to appreciate the diversity of possible pathways in scientific inquiry SI.

- Theme 3: testing theories and hypotheses come next with a mean value ( $M=3.81$ ), indicating a strong acknowledgment of the importance of testing in science and the necessity to verify hypotheses and theories in various ways.

- Theme 6: creativity and imagination in science presents a mean value ( $M=3.62$ ), highlighting the recognition of the role of imagination and creativity in science, although this perception is less unanimous than for the preceding themes

- Themes 2: limits of science and themes 8: society and culture (whether they influence science or not) display mean values ( $M=3.60$ ) and ( $M=3.52$ ), respectively, indicating a moderate understanding of the limits of science and the potential influence of society and culture on scientific practice.

- Theme 5: construction of theories obtains the lowest mean ( $M=3.48$ ), highlighting a moderate perception among teachers regarding the construction of theories. With particular attention to the specific statement "theories are constructed, not simply read in nature", which received a relatively low mean value of 2.89. These results underscore the need to deepen the understanding of theory construction in the context of teacher training.

Based on this categorization, it can be concluded that the majority of surveyed education professionals (future teachers, practicing teachers, trainers, and pedagogical inspectors) hold well-formed conceptions on various aspects of the NOS as evaluated by the examined themes. However, a portion of these teachers exhibits less consistent conceptions on these same aspects. In Morocco, as in other study contexts [22], science teachers rarely have the opportunity to become familiar with epistemology and the NOS during their training or personal studies. Despite the scarcity of research on teachers' conceptions in Morocco, these results engender a relevant discussion, highlighting potentially significant implications for research in science education.

To identify whether there is a correlation between the understanding of the NOS and the profile of the respondents, we conducted a bivariate ANOVA between the overall Nature of Science (NOS) score, calculated from the scores of the eight constituent themes, and the personal information of the respondents. This study revealed that only the position held by education professionals ( $r = 0.303, p < 0.01$ ) and their years of experience in the field ( $r = 0.231, p < 0.01$ ) show a significant correlation

with the NOS scores. Calculating the mean and standard deviation of respondents' answers to all statements on the NOS based on these two parameters yielded the result in Table 4.

Table 4. Mean values and standard deviation of responses regarding the nature of science, based on respondents' positions and years of experience

		Mean values	Standard deviation
Respondents' position	Teacher	3.65	0.52
	Trainee teacher	3.51	0.57
	Trainer	3.77	0.41
	Pedagogical inspector	4.34	0.38
Seniority	Under a year	3.41	0.48
	from 1 to 5 years	3.78	0.41
	from 5 to 10years	3.71	0.60
	from 11 to 15 years	3.92	0.45
	More than 15 years	3.86	0.53

Based on mean values, it appears that pedagogical inspectors possess the highest understanding of NOS, followed by trainers and practicing teachers, with student teachers ranking the lowest. This comprehension of NOS seems to enhance with increasing years of experience. However, upon considering standard deviations, they are relatively high across all categories, indicating significant variability within each group. This suggests that, although there may be differences in NOS scores based on respondents' positions or seniority, the variability within each group is notable, making it challenging to draw definitive conclusions. This complexity underscores the need for further research to gain deeper insights into the factors influencing teachers' understanding of NOS.

A profound understanding of NOS is undoubtedly an asset for pedagogical inspectors and trainers. It enables them to better evaluate teaching practices and approaches, ensuring the integration of essential scientific elements into teaching methodologies, it empowers them to guide teachers in adopting a scientific approach and supports them in enhancing their scientific skills. The significant correlation between NOS scores and years of experience is largely attributed to professionals with over 11 years of teaching experience. Indeed, inspectors and trainers, who typically possess extensive teaching experience, have developed a diverse range of pedagogical practices, enabling them to update their scientific knowledge and develop a comprehensive understanding of science and its nature.

#### 4.2. Teachers' Knowledge About Science Teaching

The analysis of the responses regarding science teaching (Table 2) revealed a general positive consensus among participants, with mean values predominantly in the moderate range and low standard deviations, suggesting convergence opinions.

- Theme 2: Difficulties in Science Teaching received the highest mean ( $M = 3.62$ ), indicating teachers' awareness of challenges such as insufficient historical context, limited subject knowledge and training, curriculum overload, and student motivation issues.

- Theme 4: Improving Science Teaching followed closely ( $M = 3.60$ ), reflecting recognition of the need to integrate

history and epistemology of science into training, encourage interdisciplinary collaboration, and implement strategies to enhance students' scientific skills.

- Theme 3: Science Teaching Methodology ( $M = 3.34$ ) emphasized the importance of active learning approaches, classroom collaboration, clear presentation of scientific concepts, and attention to students' initial conceptions.
- Theme 1: Aims of Science Teaching ( $M = 3.34$ ) highlighted the importance of preparing students as researchers, equipping them for higher education and 21st-century challenges, and fostering reusable scientific knowledge, while also showing some divergence in opinions regarding the transmission of scientific knowledge.

**4.3. Relationship between Teachers' Knowledge and Beliefs About NOS and their Science Teaching Practices**

Correlation coefficients were computed between the overall NOS score and science teaching themes to assess system sensitivity between epistemological inputs and instructional outputs. As shown in Table 4, stronger NOS understanding corresponds to more effective and reflective teaching strategies, indicating a positive system response.

Table 5. Correlation between NOS score and science education themes

		NOS
Science education themes	Aims of science teaching	0.410 <sup>b</sup>
	Difficulties in science teaching	0.418 <sup>b</sup>
	Science teaching methodology	0.216 <sup>a</sup>
	Improving science teaching	0.508 <sup>b</sup>

<sup>a</sup>: The correlation is statistically significant at the threshold of 0.05 level (two-tailed).

<sup>b</sup>: The correlation is statistically significant at the threshold 0.01 level (two-tailed)

The analysis of correlations reveals that the overall Nature of Science (NOS) score exhibits varying degrees of association with different themes of science teaching. The strongest correlation was observed with Improving Science Teaching ( $r = 0.508$ ), followed by Difficulties in Science Teaching ( $r = 0.418$ ) and Aims of Science Teaching ( $r = 0.410$ ). The weakest correlation was found with Science Teaching Methodology ( $r = 0.216$ ). All correlations were statistically significant at the 0.01 or 0.05 level, indicating that these relationships are unlikely to be due to chance.

These findings suggest that a stronger understanding of NOS contributes to more effective classroom science teaching. For instance, teachers with a well-developed conception of the nature of science are more likely to align their instructional approaches with the objectives of science education. This aligns with previous research showing that a teacher's epistemological stance influences their selection of pedagogical activities, whether consciously or unconsciously [12-23]. Specifically, a teacher's understanding of science, the work of researchers, and the cognitive processes involved in learning shapes their pedagogical approach. Teachers with a strong grasp of NOS are more likely to implement inquiry-based strategies that promote exploration, discovery, and experimentation. Such teachers encourage

students to ask questions, formulate hypotheses, conduct experiments, and critically analyze results.

While informed views of NOS generally correlate with effective classroom practice, later studies suggest a more complex relationship between teachers' NOS conceptions and their pedagogical behaviors [24]. Consequently, researchers have further investigated how teachers' views of NOS influence classroom pedagogy [25-26]. The observed correlations indicate that improving teachers' understanding of NOS could positively influence their science teaching practices, including instructional goals, methodologies, and the management of challenges in the classroom. However, further research is needed to establish causal relationships and to evaluate the impact of teachers' NOS understanding on students' development of scientific conceptions. These findings provide a basis and impetus for such future research endeavors [27].

**5. CONCLUSION**

This study analyzed Moroccan Life and Earth Sciences teachers' understanding of the Nature of Science (NOS) and its impact on modeling-based teaching strategies. The results show that well-developed NOS conceptions, particularly among experienced teachers, inspectors, and trainers, are associated with more reflective and effective teaching strategies, especially in problem-based instruction, inquiry-based implementation, and learning outcomes. From a systems perspective, teachers' NOS understanding functions as a critical epistemological input that drives instructional modeling processes and shapes learning outputs. Strong NOS knowledge enables the design of learning activities focused on system analysis, model construction, and problem-solving, while gaps in NOS understanding limit coherent, inquiry-based instructional approaches.

These findings highlight optimization potential: teacher training programs, instructional strategies, and student learning outcomes form a reproducible system that can be scaled across different educational and technical contexts.

❖ Engineering-Style Take aways:

- What can be modeled: Teacher-student interactions, instructional strategies, learning system dynamics
- What can be measured: NOS understanding, teaching effectiveness, student performance indicators
- What can be optimized: Teacher training programs, instructional design, modeling-based learning processes

**6. IMPLICATIONS FOR ENGINEERING-BASED TRAINING AND TECHNICAL EDUCATION**

Beyond science education, the proposed epistemological input-modelling process-learning output framework is transferable to engineering and technical training contexts. In engineering education, epistemic awareness of model assumptions and limitations supports effective system abstraction, simulation, and predictive reasoning. For example, in mechanical systems training, understanding modelling assumptions (e.g., linearity, friction, boundary conditions) enhances learners' ability to

develop and validate dynamic models. Similarly, in process modelling and control systems education, epistemological competence supports parameter identification, system optimization, and predictive decision-making. Accordingly, the findings contribute to the design of system-based learning environments-such as simulations, virtual laboratories, and technical training platforms-where modelling, feedback, and optimization are central to learning effectiveness.

**7. LIMITATIONS AND FUTUR RESEARCH**

Teachers were chosen as the focal group because we posit that advancements in scientific education will occur solely when teachers exhibit well-informed perspectives on the NOS and can effectively showcase their understanding through practical application. One of the limitations of this study is that we did not seek ethical approval for its conduct. This decision was taken after careful evaluation of the nature of our research, which involved (exploring teacher's conceptions about the nature of science). As our study did not involve sensitive data, or potential harm to participants, we judged that ethical approval was not required. This assessment was based on the guidelines provided by research laboratory, which set out the criteria for determining the need for ethical approval.

Nevertheless, we recognize the importance of ethical considerations in research and have taken steps to ensure that our study adheres to ethical principle, including transparency and consistency in the conduct of the study, confidentiality and anonymity of participant data, It should be noted that this decision could have implications for the interpretation and generalizability of the results of our study, and we encourage future research that addresses this issue in an ethically compliant manner. The result of this study underscores the necessity for more investigation to explore the connection between teachers' NOS beliefs and their instructional strategies, conducting a thorough qualitative study involving several teachers would significantly enhance the depth and value our finding. Different tools can be used to collect more data such as classroom observations, teacher reflections, instructional notes, and interviews.

**NOMENCLATURES**

**1. Acronyms**

ANOVA	Analysis of Variance
LES	Life and Eart Science
NOS	Nature of science
SPSS	Statistical Package for the Social Sciences
SI	Science Inquiry
RQ	Research question
MENA	Middle Eastern and North African

**2. Symbols / Parameters**

*M*: The mean values  
*r*: The Pearson correlation coefficient

**REFERENCES**

[1] T.D. Teshale, R.D. Negasi, D.A. Getahun, “Exploring Ethiopian Secondary School Science Teachers’ Conceptions About the Nature of Scientific Knowledge (NOSK)”, *Education Sciences*, Vol. 14, No. 6, p. 559, 2024.

[2] D.K. Capps, B.A. Crawford, “Inquiry-Based Professional Development: What Does it Take to Support Teachers in Learning About Inquiry and Nature of Science?”, *International Journal of Science Education*, Vol. 35, No. 12, pp. 1947-1978, 2013.

[3] N.G. Lederman, J.S. Lederman, “Teaching and Learning of Nature of Scientific Knowledge and Scientific Inquiry: Building Capacity Through Systematic Research-Based Professional Development”, *Journal of Science Teacher Education*, Vol. 30, No. 7, pp. 737-762, 2019.

[4] S. Alhamlan, H. Aljasser, A. Almajed, S.H. Omar, “Trends of the Arabic Research on the Nature of Science”, *International Education Studies*, Vol. 11, No. 5, pp. 110-122, 2018.

[5] M.R. Librea Carden, F. Avarzamani, P. Rillero, F. Hamel, “Nature of Science Understandings and Instructional Perceptions: Moroccan Preservice Primary Science Teacher Educators’ Responding Variables to a Professional Development Series”, *Electronic Journal for Research in Science and Mathematics Education*, Vol. 26, No. 4, pp. 1-16, 2023.

[6] UNESCO, “Education in Morocco: Sector Analysis”, pp. 53-54, 2010.

[7] African Development Bank, “Analysis of the Education and Training System in Morocco: Economic and Sectoral Study”, p. 45, 2013.

[8] N.G. Lederman, “Students’ and Teachers’ Conceptions of the Nature of Science: A Review of the Research”, *Journal of Research in Science Teaching*, Vol. 29, No. 4, pp. 331-359, 1992.

[9] G. Bachelard, “The Formation of the Scientific Mind”, Paris, France, J. Vrin, 1967.

[10] T. Kuhn, “The Structure of Scientific Revolutions”, Paris, France, Champ Flammarion, 1970.

[11] S. Boujaoude, G. Santourian, “The Status of the Nature of Science in Science Education in Lebanon”, in *Teaching and Learning Science in the Developing World*, N. Halai, M. Iqbal, Eds. Karachi, Pakistan: Aga Khan University, 2010.

[12] P. Feyerabend, “Against Method: An Outline of an Anarchist Theory of Knowledge”, *The Threshold*, Paris, France, 1979.

[13] G. Fourez, M. Larochele, “Taming Epistemology”, Brussels, Belgium: De Boeck, 2009.

[14] J.Y. Cariou, “Developing Scientific Thinking, Three Theoretical Approaches, One Practical Tool”, *Diphtheric*, 2002.

[15] N.G. Lederman, A. Antink, S. Bartos, “Nature of Science, Scientific Inquiry, and Socio-Scientific Issues Arising from Genetics: A Pathway to Developing a Scientifically Literate Citizenry”, *Science and Education*, Vol. 23, pp. 285-302, 2014.

- [16] Y. Hatim, "Morocco's New Primary School Curricula focus on Science, Math", Morocco World News, August 2020.
- [17] A. Moufti, M. Taoufik, R. Elmoubarki, A. Abouzaid, A. Lamsalmi, N. Barka, "Survey of Teaching of Scientific Awakening in Moroccan Rural Primary Schools", American Journal of Innovative Research and Applied Sciences, Vol. 11, No. 2, pp. 81-88, 2020.
- [18] L.L. Liang, S. Chen, X. Chen, O.N. Kaya, A.D. Adams, M. Macklin, J. Ebenezer, "Student Understanding of Science and Scientific Inquiry (SUSSI): Revision and Further Validation of an Assessment Instrument", in Proc. Annual Conf. National Association for Research in Science Teaching (NARST), San Francisco, Vol. 122, CA, USA, April 2006.
- [19] T. Lombrozo, A. Thanukos, M. Weisberg, "The Importance of Understanding the Nature of Science for Accepting Evolution", Evolution: Education and Outreach, Vol. 1, pp. 290-298, 2008.
- [20] F. Le Poutier, "Social Work, Social Maladjustment and Cognitive Processes", Paris, France, Cnterhi, Distributed by PUF, 1986.
- [21] S. Boubih, E. Assimi, M. El Qryefy, H. Seghir, G. Ghariz, N. Boucetta, R. Janati Idrissi, "Factors Influencing Learner Engagement: A Case Study of Middle and High School Students", International Journal of Science Didactics and Educational Engineering, Vol. 1, No. 1, pp. 59-74, 2023.
- [22] W.F. McComas, "Understanding How Science Works: The Nature of Science as the Foundation for Science Teaching and Learning", School Science Review, Vol. 98, No. 365, pp. 71-76, 2017.
- [23] L.H. Zbidi, "Relationship Between Epistemological Stance and Teaching Practices: Influence of Biology Teachers' Epistemological Stances on Their Development of Teaching Situations on Blood Circulation", Saarbrucken, Germany, European University Press, 2010.
- [24] D.L. Zeidler, "Dancing with Maggots and Saints, Visions for Subject Matter Knowledge, Pedagogical Knowledge, and Pedagogical Content Knowledge in Science Teacher Education Reform", Journal of Science Teacher Education, Vol. 13, No. 1, pp. 27-42, 2002.
- [25] K.J. Chuene, S.K. Singh, "Exploring Science Teachers' Views About the Nature of Science and the Implications on Their Pedagogical Content Knowledge: A Case of 11 in-Service South African Teachers", EURASIA Journal of Mathematics, Science and Technology Education, Vol. 20, No. 1, pp. 23-84, 2024.
- [26] S. Waters Adams, "The Relationship Between Understanding of the Nature of Science and Practice: The Influence of Teachers' Beliefs About Education, Teaching and Learning", International Journal of Science Education, Vol. 28, No. 8, pp. 919-944, 2006.
- [27] H. Seghir, N. Boucetta, S. Boubih, M. Al Alaoui, R. J. Idrissi, G. Ghariz, "Towards a New Relationship Between Innovative Ideas and Designs Adopted by Teachers for Improving the Study Environment of Life and Earth Sciences in Morocco", E3S Web of Conferences, Vol. 412, p. 01015, The Ulis, France, EDP Sciences, 2023.

## BIOGRAPHIES



**Name:** Hakima  
**Surname:** Seghir  
**Birthday:** 08.05.1984  
**Birthplace:** Taza, Morocco  
**Bachelor:** Biology, Applied Biology Option, Taza Poly-Disciplinary Faculty, Sidi Mohamed Ben Abdellah University,

Fes, Morocco, 2012

**Master:** Education, Specializing in SVT Pedagogy, Higher Normal School, Abdelmalek Essaadi University, Tetouan, Morocco, 2018

**Doctorate:** Educational Engineering and Science Didactics, Higher Normal School, Abdelmalek Essaadi University, Tetouan, Morocco, 2024

**Scientific Position:** Assoc. Prof., High Normal School, Moulay Ismail University, Meknes Morocco, Since 2024

**Research Interests:** Didactics of Science, Epistemology, History of Science

**Scientific Publications:** 32 Papers, 1 Thesis



**Name:** Mohamed  
**Surname:** Serghini  
**Birthday:** 20.03.1991  
**Birthplace:** Kenitra, Morocco  
**Bachelor:** Physics, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco, 2012

**Master:** Teaching and Training Professions in Physics and Chemistry Sciences, Faculty of Sciences, Ibn Tofail University, Kenitra, Morocco, 2015

**Doctorate:** Didactics of Sciences at Faculty of Science Ben M'Sik, Hassan II University, Casablanca, Morocco, 2023

**Scientific Position:** Assoc. Prof., Science Didactics, Department of Education Science and Teaching Technology, High Normal School of Meknes, Moulay Ismail University, Meknes, Morocco, Since 2024

**Research Interests:** Didactics of Sciences, Analysis of Teaching Practices

**Scientific Publications:** 7 Papers, 1 Thesis



**Name:** Najat  
**Surname:** Boucetta  
**Birthday:** 10.01.1970  
**Birthplace:** Khenifra, Morocco  
**Bachelor:** Midwifery, Institute for Health Careers Training IFCS Tetouan, Morocco, 1997

**Master:** Sexual and Reproductive Health Expertise, International University of Andalusia, Baeza, Jaen, Spain, 2008

**Master:** Pedagogy of Nursing Sciences and Health Techniques, Higher Institute of Nursing Professions and Health Techniques, Tetouan, Morocco, 2019

**Doctorate:** Health Sciences and Nursing Education and Didactics, Research Team in Educational Engineering and Science Didactics, Higher Normal School, Abdelmalek Essaadi University, Tetouan, Morocco, 2024

**Scientific Position:** Lecturer, Higher Institute of Nursing

Professions and Health Techniques, Tetouan, Morocco, Since 2003

Research Interests: Geriatric Nursing, Health Sciences Education, University Pedagogy, Pedagogical Innovation, Midwifery Practice, Clinical Simulation, Therapeutic Patient Education, Quality of Care, and Professional Communication in Healthcare

Scientific Publications: 25 Papers



Name: **Said**

Surname: **Boubih**

Birthday: 24.09.1981

Birthplace: Agadir, Morocco

Bachelor: Valorization of Local Products and Know-How, Faculty of Sciences, Ibn Zohr University, Agadir, Morocco, 2010

Master: Biotechnologies and Valorization of Plant Resources, Faculty of Sciences, Ibn Zohr University, Agadir, Morocco, 2012

Doctorate: Pedagogical Engineering and Didactics of Life and Earth Sciences, Specialization in Life and Earth Sciences, Faculty of Sciences, Abdelmalek Essaadi University, Tetouan, Morocco, 2022

Scientific Position: Assist. Prof., Higher Institute of Nursing Professions and Health Techniques, Tangier, Morocco, Since 2023

Research Interests: Pedagogical Engineering, Science Didactics, Flipped Learning

Scientific Publications: 33 Papers, 2 Book, 2 Projects, 1 Thesis

Scientific Memberships: Member of Scientific Committee of International Journal of Science Didactics and Educational Engineering (IJSDEE)



Name: **Abdelkader**

Surname: **Ouhtit**

Birthday: 01.01.1976

Birthplace: Oulmes, Morocco

Bachelor: Animal Biology, Faculty of Sciences, Abdelmalek Essaadi University, Tetouan, Morocco, 1998

Master: Didactics of Life and Earth Sciences, Higher Normal School, Faculty of Sciences, Abdelmalek Essaadi University, Tetouan, Morocco, 2022

Doctorate: Science Education (Didactics of Sciences), Higher Normal School, Faculty of Sciences, Abdelmalek Essaadi University, Tetouan, Morocco, 2025

Scientific Position: Inspector of Life and Earth Sciences,

Regional Academy of Education and Training, Tanger-Tetouan-Al Hoceima, Morocco, Since 2014

Research Interests: Science Education, Immunology Education, Information and Communication Technologies in Education, Language of Instruction and Scientific Learning, Epistemology and History of Science

Scientific Publications: 9 Papers, 4 Book Chapters



Name: **Ghizlane**

Surname: **Ghariz**

Birthday: 11.09.1987

Birthplace: Midult, Morocco

Bachelor: Applied Plant Science, Faculty of Science and Technology, Moulay Ismail University, Errachidia, Morocco,

2010

Master: Pedagogy in Life and Earth Sciences, Normal High School, Abdelmalek Essaadi University, Tetouan, Morocco, 2018

Doctorate: Pedagogical Engineering and Didactics of Sciences, Specialization in Life and Earth Sciences, Faculty of Sciences, Abdelmalek Essaadi University, Tetouan, Morocco, 2025

Scientific Position: Teacher, Life and Earth Sciences in Secondary Education, Tetouan, Morocco, Since 2011

Research Interests: Pedagogical Engineering, Science Didactics

Scientific Publications: 17 Papers, 2 Books, 1 Thesis



Name: **Youssef**

Surname: **Ou Sekou**

Birthday: 15.04.1985

Birthplace: Meknes, Morocco

Bachelor: Applied Mathematics, Faculty of Science, Moulay Ismail University, Meknes, Morocco, 2007

Master: Mathematics and Engineering Applications, Faculty of Science, Moulay Ismail University, Meknes, Morocco, 2013

Doctorate: Sciences Didactics, Pedagogical Engineering and ICT, Faculty of Sciences Dher Elmahraz, Sidi Mohamed Ben Abdellah University, Fes, Morocco, 2022

Scientific Position: Assist. Prof., Mathematics/Didactic of Mathematics, Higher Normal School, Moulay Ismail University, Meknes, Morocco, Since 2023

Research Interests: Didactic of Mathematic, Pedagogical Engineering and ICT, Digital Culture of Teachers, Epistemological Beliefs

Scientific Publications: 7 Papers, 1 Thesis