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Science Teachers Perceptions of the Nature of Science (NOS) and the Nature of Scientific Inquiry (NOSI)

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Abstract: This study aims to analyze science teachers' perceptions of the Nature of Science (NOS) and Nature of Scientific Inquiry (NOSI), including their understanding of the nature of scientific knowledge, the scientific method, and the challenges in its implementation in the classroom. A survey method was employed, involving 61 science teachers from various educational levels. The findings reveal that 59% of teachers agreed and 34.4% strongly agreed that they understand the nature of science and apply it in their teaching. Additionally, 65.6% agreed and 26.2% strongly agreed that scientific knowledge is tentative and continually evolving. Regarding the scientific method, 49.2% agreed and 44.2% strongly agreed that science is based on empirical evidence and can be tested. However, despite a general understanding of the importance of inquiry-based approaches, 47.5% disagreed and 14.8% strongly disagreed with the effectiveness of the inquiry model in science education, indicating significant challenges in its implementation. Factors such as limited facilities, time constraints, and students' readiness were identified as key obstacles to the optimal integration of NOS and NOSI. Therefore, enhanced teacher training, infrastructure support, and more adaptable teaching strategies are essential to ensure the effective implementation of NOS and NOSI in science education.

Keywords: inquiry-based learning; nature of science; nature of scientific inquiry; scientific method; teacher perception

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Introduction

The Nature of Science (NOS) and Nature of Scientific Inquiry (NOSI) are critical constructs in science education that significantly influence how scientific knowledge is perceived and imparted in educational settings. NOS pertains to the understanding of science as a dynamic and evolving discipline, reliant on empirical evidence and subject to modification with new findings. This perspective is essential for fostering a scientific mindset among students, as it encourages them to view science not merely as a collection of immutable facts but as an ongoing process of inquiry and discovery (Zhang et al., 2021; KARTAL et al., 2018). Conversely, NOSI focuses on the methodologies of scientific inquiry, which include observation, experimentation, and data analysis, thereby enabling students to engage actively in the scientific process (Schizas et al., 2024; Mesci et al., 2020). Science educators are instrumental in conveying these principles, ensuring that students grasp the operational aspects of science and its epistemological foundations (Erduran et al., 2020; Lederman & Lederman, 2019).

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Despite the recognized importance of NOS and NOSI in science education, their effective implementation remains fraught with challenges. Research indicates that teachers often possess varying degrees of understanding regarding these concepts, with some educators still adhering to a view of science as absolute and unchanging (Trnová, 2019; Kaya et al., 2018). This misconception can lead to a disconnect between theoretical knowledge and practical application, particularly in the context of inquiry-based learning, which is essential for engaging students in scientific processes (Stefanidou et al., 2018; Ayvacı & Özbek, 2019). Factors such as insufficient laboratory resources, rigid curricular frameworks, and inadequate professional development opportunities further complicate the integration of NOS and NOSI into classroom instruction (Akgün & Kaya, 2020; Mesci et al., 2020).

Moreover, the perceptions that teachers hold about the tentative nature of scientific knowledge and the scientific method significantly shape their pedagogical approaches. If educators view science as a final and fixed body of knowledge, they may inadvertently transmit this perspective to their students, who may then regard science as a mere repository of facts rather than an exploratory endeavor (Lederman & Lederman, 2019; Yeh et al., 2019). The complexity of inquiry-based methods can also pose challenges for teachers, as these approaches require not only advanced experimental skills but also a supportive learning environment conducive to exploration and discovery ("Teaching natural sciences through the prism of philosophy: an attempt to define the relationship", 2022; Alsahou & Alsammari, 2019). Nonetheless, evidence suggests that when effectively implemented, inquiry-based learning can enhance students' critical thinking abilities and deepen their comprehension of scientific concepts (Choudhary et al., 2020; Dorji et al., 2022).

In summary, the successful integration of NOS and NOSI into science education is contingent upon teachers' understanding and attitudes towards these concepts. Addressing the gaps in teachers' perceptions and providing robust professional development opportunities are essential steps toward fostering a more profound and accurate understanding of science among students (Mesci et al., 2020; Mesci et al., 2019).

Given the importance of NOS and NOSI in science education, further investigation is needed to explore how science teachers understand and apply these concepts in their instructional practices. Prior research has predominantly focused on students' perceptions of science and the scientific method, whereas studies examining teachers' comprehension as the primary facilitators of science education remain limited. Therefore, this study aims to analyze science teachers' perceptions of NOS and NOSI, specifically their understanding of the nature of scientific knowledge, the application of the scientific method in teaching, and the challenges associated with implementing inquiry-based approaches. By examining how science teachers perceive NOS and NOSI, this research seeks to provide valuable insights for the development of more effective teaching strategies and to contribute to the enhancement of science education quality in schools

Method

This study employed a survey method to examine science teachers' perceptions of the Nature of Science (NOS) and Nature of Scientific Inquiry (NOSI). The survey involved 61 respondents, consisting of science teachers from various educational levels, including junior high schools (SMP), Islamic junior high schools (MTs), and senior high schools (SMA) across different regions of Indonesia. The respondents were selected through purposive sampling, based on the criterion that they were actively teaching science subjects, ensuring that their perspectives on the understanding and application of NOS and NOSI in science instruction were relevant.

Data were collected using a Likert-scale questionnaire, which comprised several sections, including respondents' demographic characteristics, teaching experience, and their opinions on various aspects of NOS and NOSI. The demographic characteristics examined included gender, age, highest level of education attained, school location, certification status, grade levels taught, and teaching experience. Among the total respondents, the majority held undergraduate (S1) and postgraduate (S2) degrees, with teaching experience ranging from less than five years to more than fifteen years.

The questionnaire contained Likert-scale statements designed to measure respondents' levels of agreement regarding various NOS and NOSI aspects, such as their understanding of the nature of science, the tentative nature of scientific knowledge, the significance of the scientific method, the use of inquiry-based learning in science education, and the challenges associated with its implementation in classrooms. The collected data were analyzed quantitatively by examining the distribution of response percentages for each statement. This analysis aimed to identify general patterns in science teachers' perceptions of NOS and NOSI, as well as to explore potential factors influencing the application of these concepts in science instruction.

Result and Discussion

Description and Critical Analysis of Science Teachers' Perceptions of the Nature of Science (NOS)

Understanding and Application of NOS in Teaching

The majority of science teachers demonstrate a strong understanding of the Nature of Science (NOS) and its application in teaching. Recent studies indicate that 59% of teachers agree and 34.4% strongly agree that they comprehend NOS concepts and have implemented them in their classroom instruction (Gathong & Chamrat, 2019 ;Dmitrievna, 2024). Notably, no teachers expressed extreme disagreement regarding their understanding of NOS, with only 5% somewhat disagreeing and 1.6% strongly disagreeing. Furthermore, 59% of teachers agreed and 23% strongly agreed that NOS has been integrated into science education, suggesting that while teachers possess a fairly good understanding of NOS, there remains a notable gap in the actual implementation of these concepts in schools (Grinnell, 2021; Borys, 2022).

Although most teachers claim to understand and apply NOS, a small percentage remains uncertain or does not fully integrate these concepts into their teaching. This discrepancy can be attributed to several factors, including a lack of systematic training, limited resources, or insufficient exposure to teaching science through approaches aligned with NOS principles (James et al., 2021; "Teaching natural sciences through the prism of philosophy: an attempt to define the relationship", 2022). Research highlights that professional development and training programs focused on NOS are essential for enhancing teachers' competencies and ensuring effective integration of NOS into their instructional practices (Velychko et al., 2022; Clough, 2018). Therefore, additional training and mentoring programs on NOS implementation in classrooms are crucial to improving the quality of science education in schools (Trnová, 2019; Budiastra et al., 2020).

In conclusion, while a significant proportion of science teachers express confidence in their understanding of NOS, the challenges in actual classroom implementation underscore the need for targeted professional development initiatives. Addressing these gaps will not only enhance teachers' pedagogical skills but also foster a more profound understanding of scientific principles among students, ultimately contributing to a more effective science education framework (Tampe & Spatz, 2022; McComas & Clough, 2020)..

The Tentative and Evolving Nature of Scientific Knowledge

Teachers' understanding of the tentative nature of scientific knowledge exhibits a positive trend, with 65.6% agreeing and 26.2% strongly agreeing that science, including natural sciences, is tentative and subject to revision based on new research findings. Only 6.6% somewhat disagreed and 1.6% disagreed, indicating that most teachers recognize the evolving nature of science rather than perceiving it as absolute and unchanging.

However, perceptions regarding the purpose of science remain diverse. While 45.9% agreed and 18% strongly agreed that the primary goal of science is not to establish absolute truths, 26.2% somewhat disagreed, 6.6% disagreed, and 3.3% strongly disagreed. This suggests that some teachers still perceive science as a means to discover absolute truths, whereas in scientific philosophy, science aims to construct models that approximate reality based on empirical evidence.

Similarly, when asked about how scientific theories evolve when confronted with conflicting evidence, 49.2% agreed and 14.8% strongly agreed, but 29.5% somewhat disagreed and 6.5% disagreed with this notion. This indicates that a portion of teachers lack a full understanding of how scientific theories develop and change over time. Such misconceptions could affect their teaching approach, particularly in helping students understand that science is an ongoing process of refinement based on new evidence.

Empirical Basis and Objectivity in Science

Most teachers understand that science is based on empirical evidence and must be testable. Recent findings indicate that 49.2% of teachers agree and 44.2% strongly agree with this principle, reflecting a robust awareness that scientific inquiry must be rooted in verifiable data (Al-Omari, 2022). This understanding is crucial, as it aligns with the philosophical underpinnings of science that emphasize the importance of empirical observation and systematic experimentation in the construction of scientific knowledge ("Scientific Knowledge in Bacon Philosophy: Insights from Dialectical Materialism", 2024). Additionally, a significant majority of teachers acknowledge that repeated testing is necessary to eliminate subjectivity in scientific research, with 41% agreeing and 54.1% strongly agreeing. This highlights an essential aspect of scientific methodology, where replication serves as a means to validate findings and ensure objectivity (Clough et al., 2020).

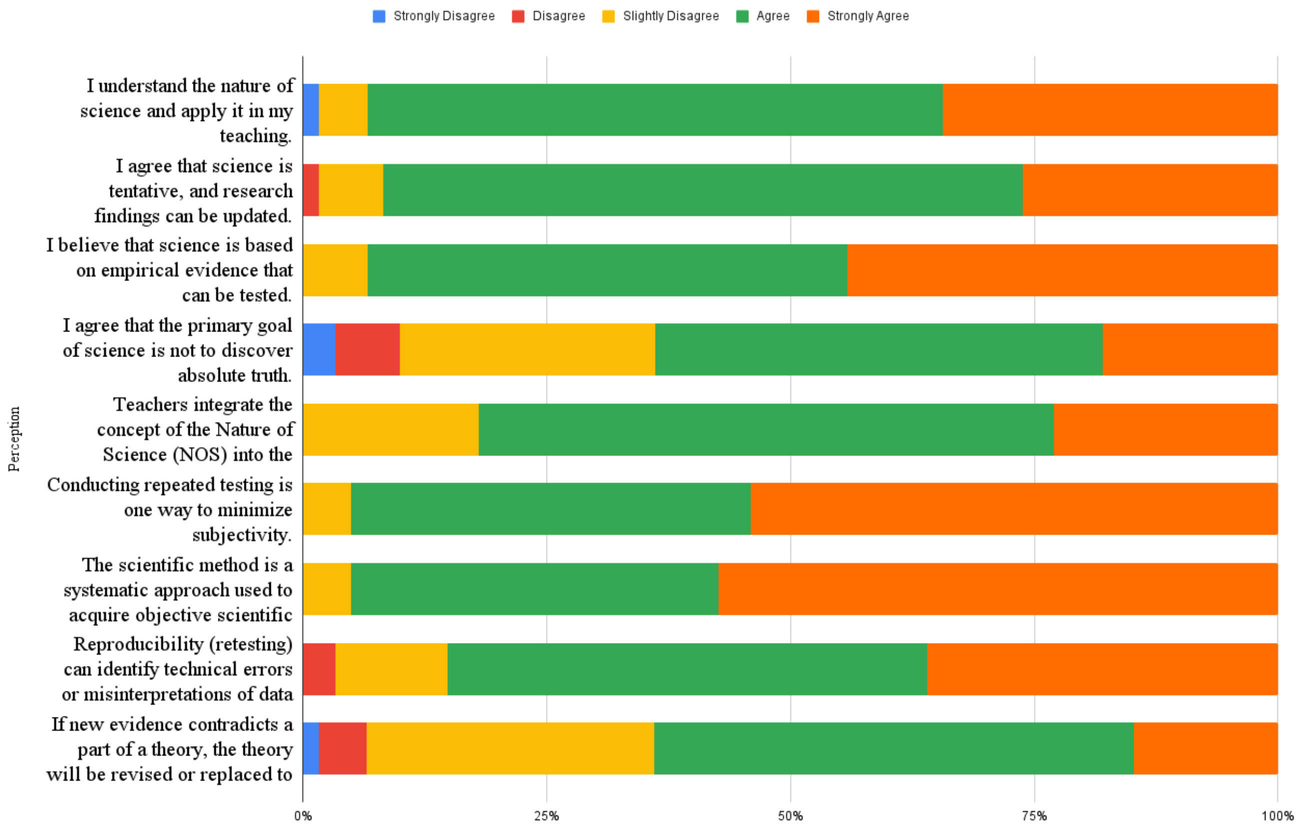

Figure 1. Science Teachers' Perceptions of the Nature of Science (NOS)

Regarding reproducibility in science, 49.2% of teachers agreed and 36% strongly agreed that repeated experiments help identify technical errors or misinterpretations in initial studies. However, 11.5% somewhat disagreed and 3.3% disagreed, suggesting that not all teachers fully grasp the importance of replication in the scientific verification process (Al-Omari, 2022). A strong understanding of reproducibility is crucial in science education to ensure that students do not perceive science as dogmatic but rather as a discipline involving continuous testing and evaluation (Edmondson et al., 2020). This perspective is essential for fostering a scientific mindset among students, as it encourages them to appreciate the iterative nature of scientific inquiry and the necessity of critical examination of results (Gathong & Chamrat, 2019). While a significant proportion of science teachers demonstrate a solid understanding of the empirical basis of science and the necessity for reproducibility, there remains a need for ongoing professional development to bridge the gaps in understanding and implementation of these principles in classroom settings. Enhancing teachers' comprehension of these concepts will ultimately contribute to a more effective science education that prepares students to engage with science as a dynamic and evolving field (Al-Omari, 2022; Clough et al., 2020).

The Scientific Method as a Systematic Process in Science

The scientific method is widely recognized as a systematic approach for obtaining objective scientific knowledge. Recent data indicates that 37.7% of teachers agree and 57.4% strongly agree that the scientific method is essential, demonstrating that science teachers acknowledge its central role in both teaching and research Younis (2022)Shaheen et al., 2019). This consensus underscores the importance of the scientific method as a foundational element in science education, as it provides a structured framework for inquiry and experimentation (Lederman et al., 2019). However, in practice, not all teachers may effectively implement the scientific method in classroom instruction, which can hinder students' understanding of scientific processes (Ecevit & Kaptan, 2022).

A key challenge is ensuring that the scientific method is not only understood conceptually but also effectively applied in science education. If teachers possess only theoretical knowledge without strong practical application, students may miss the opportunity to develop deeper scientific thinking skills (Bjønness & Knain, 2018). Therefore, greater emphasis on experiential learning, investigative approaches, and scientific discussions is necessary to ensure that students experience the scientific process firsthand (Çetin, 2021). Research has shown that inquiry-based learning can significantly enhance students' engagement and understanding of scientific concepts, promoting critical thinking and problem-solving abilities (Nehring, 2019).

Overall, the data indicate that science teachers possess a relatively strong understanding of the Nature of Science (NOS), the tentative nature of scientific knowledge, the empirical basis of science, and the scientific method. However, certain aspects require further reinforcement, particularly regarding how scientific theories change over time and the importance of repeated testing in scientific research (Lederman et al., 2021; Sun et al., 2024). The findings suggest a need for continuous professional development and training programs to enhance teachers' understanding of NOS and effective implementation in the classroom (Özden & YENİCE, 2022). By strengthening these competencies, students can engage in authentic learning experiences and recognize that science is an evolving process rather than a static body of facts (Schizas et al., 2024).

Additionally, reinforcing the use of the scientific method in instruction is essential to develop students' critical and scientific thinking skills. By enhancing the quality of NOS-based teaching, science education in schools can be more effective in shaping students' scientific perspectives, which is particularly crucial in addressing the challenges of the modern information era (Al-Momani, 2019; Grooms, 2020).

Description and Critical Analysis of Science Teachers' Perceptions of the Nature of Scientific Inquiry

Understanding Inquiry in Science Education

Most science teachers demonstrate a strong understanding of the concept of inquiry in natural sciences. A majority of teachers (42.6% agreed and 54.1% strongly agreed) believe that scientific inquiry originates from curiosity about natural phenomena. This indicates that most teachers recognize that science is not solely based on memorizing concepts but emerges from questioning and exploring natural phenomena Akuma & Callaghan (2018). However, a key challenge in inquiry-based learning is how teachers can guide students in developing meaningful scientific questions and channeling their curiosity into a structured scientific investigation. Research suggests that teachers who view practical work as an experiential ground for learning are more likely to adopt inquiry-based strategies, which can enhance students' engagement and understanding of scientific concepts (Erman et al., 2018).

Additionally, teachers acknowledge that scientific inquiry should be open to validation and testing by others, with 62.3% agreeing and 16.4% strongly agreeing with this principle. However, 19.7% somewhat disagreed and 1.6% disagreed, suggesting that some teachers may not fully grasp that scientific knowledge progresses through peer review and repeated experimentation within the scientific community (Rubini et al., 2019). If this principle is not emphasized in classroom instruction, students may develop a misconception that science is dictated by authority rather than being subject to ongoing revision based on new findings. This highlights the importance of fostering an understanding of the collaborative nature of scientific inquiry, which is essential for developing scientifically literate individuals who can critically evaluate scientific claims (Mohammed & Amponsah, 2021). While a significant proportion of science teachers demonstrate a solid understanding of inquiry in science education, challenges remain in effectively guiding students through the inquiry process. Continuous professional development and training focused on inquiry-based teaching practices are crucial for enhancing teachers' abilities to facilitate meaningful scientific inquiry in the classroom (Schiefer et al., 2019). By addressing these challenges, educators can help students appreciate the dynamic and evolving nature of scientific knowledge, ultimately fostering a more profound engagement with science (Bioco & Echaure, 2021)

Inquiry-Based Learning in Science Education

Most teachers acknowledge that inquiry-based learning emphasizes active student engagement, with 49.2% agreeing and 39.4% strongly agreeing. This reflects a growing recognition among educators that inquiry-based approaches can foster deeper learning and critical thinking skills in students Meilani & Faradiba (2019)Twahirwa et al., 2022). However, 8.2% somewhat disagreed, 1.6% disagreed, and 1.6% strongly disagreed, indicating that some teachers remain skeptical about the effectiveness of inquiry-based approaches in enhancing students' understanding. The primary challenges in implementing inquiry-based learning include limited laboratory resources, students' lack of investigative skills, and curriculum constraints that may not fully support inquiry-based instruction (Aristeidou et al., 2020).

Another widely accepted principle is that scientific inquiry involves gathering evidence to address research questions or problems, with 63.9% agreeing and 27.9% strongly agreeing with this principle. This demonstrates that most teachers recognize that science is not solely based on observation and experimentation but also requires systematic data collection and analysis (Lederman et al., 2019). If teachers fully understand this principle, they are more likely to encourage students to rely on data-driven conclusions rather than opinions or intuition. Research indicates that when teachers effectively integrate inquiry-based learning, students are more engaged in the scientific process, leading to improved understanding and retention of scientific concepts (Adeyele, 2023; Deák et al., 2021).

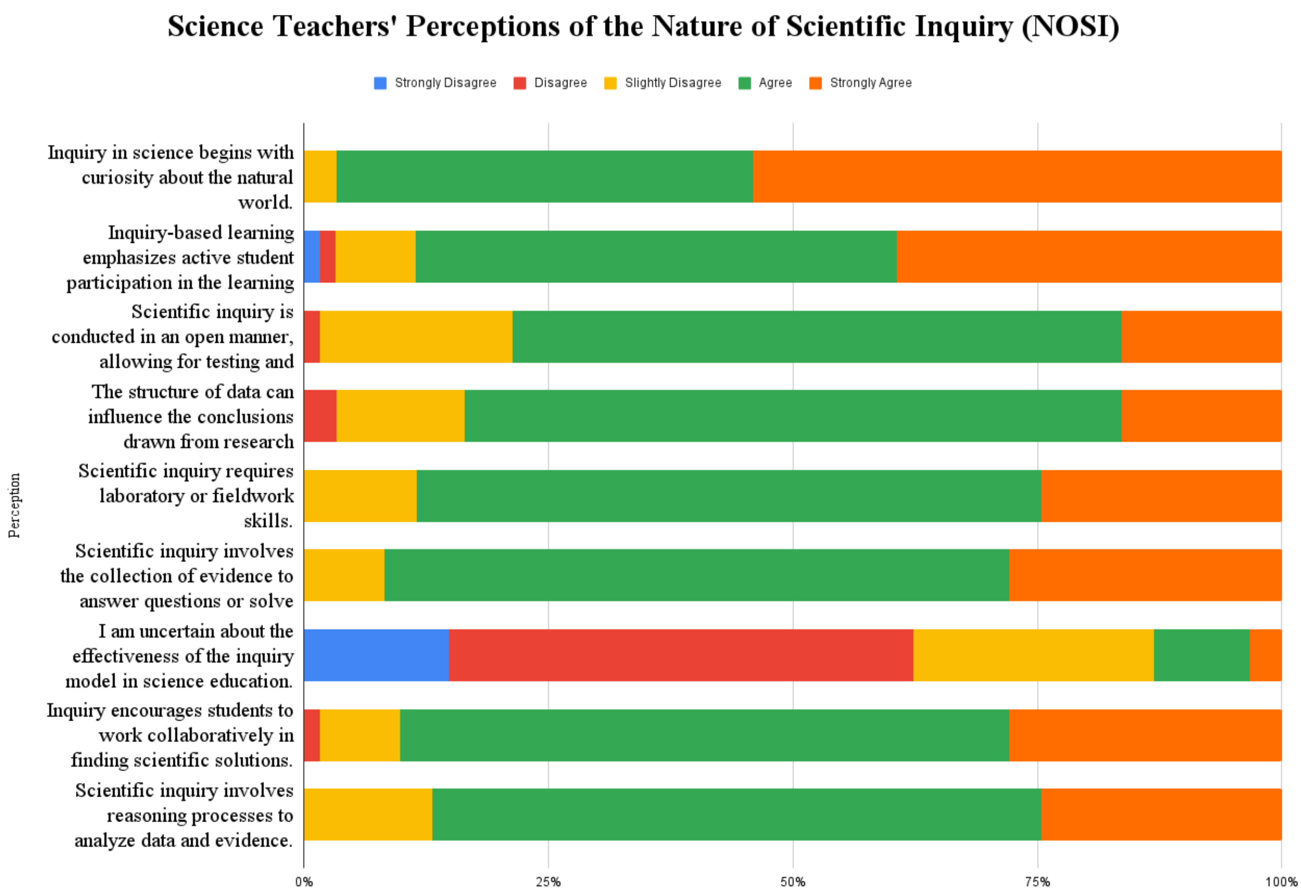

Figure 2. Science Teachers' Perceptions of the Nature of Scientific Inquiry (NOSI)

Despite teachers' understanding of the importance of inquiry in science education, their views on the effectiveness of the inquiry model remain largely skeptical. A significant 47.5% disagreed and 14.8% strongly disagreed with the statement that inquiry-based learning is effective in science education, while 24.6% somewhat disagreed. Only 9.8% agreed and 3.3% strongly agreed, revealing a substantial gap between theoretical understanding and practical implementation in classrooms (Alarcón et al., 2023; Lederman et al., 2021). Time constraints, curriculum demands, and student readiness were identified as major barriers to implementing inquiry-based teaching strategies. To address this, a more systematic approach is needed to help teachers effectively integrate inquiry-based learning into science education (Chen & Chuang, 2020). While there is a general acknowledgment of the benefits of inquiry-based learning among science teachers, practical challenges hinder its implementation. Continuous professional development and support are essential to equip teachers with the necessary skills and resources to foster inquiry-based learning effectively, ultimately enhancing students' scientific literacy and engagement (Bioco & Echaure, 2021; SALAZAR & Feliciano, 2020).

Skills Required for Scientific Inquiry

Most teachers recognize that data structure in scientific research significantly influences the conclusions drawn, with 67.2% agreeing and 16.4% strongly agreeing. However, 13.1% somewhat disagreed and 3.3% disagreed, indicating that some teachers may not emphasize data analysis as a core component of science education. If students are not trained in proper data analysis techniques, they risk drawing inaccurate or biased conclusions in their scientific investigations. Research shows that understanding data structures and analysis is crucial for developing scientific literacy, as it enables students to critically evaluate evidence and make informed conclusions (Liso et al., 2019).

Additionally, a majority of teachers acknowledge the importance of laboratory or fieldwork skills in scientific inquiry, with 63.9% agreeing and 24.6% strongly agreeing. Only 11.5% somewhat disagreed, and none outright rejected this statement. This suggests that teachers understand the significance of hands-on experimentation in scientific inquiry (Wangdi et al., 2020). However, limited laboratory facilities and students' lack of experience in conducting independent experiments remain key challenges. Therefore, providing additional resources and training for teachers to design feasible experimental activities—even with limited equipment—would be beneficial (Eti & Sığırtmaç, 2021). Inquiry-based learning has been shown to enhance students' engagement and understanding of scientific concepts, particularly when they are actively involved in hands-on investigations (Lederman et al., 2019).

Furthermore, 62.3% agreed and 24.6% strongly agreed that scientific inquiry involves reasoning to analyze data and evidence, while 13.1% somewhat disagreed. If some teachers still struggle to recognize the role of scientific reasoning in inquiry, this may impact their teaching strategies, potentially leading to students being taught scientific facts without being guided on how to interpret evidence in constructing scientific knowledge (Seneviratne et al., 2020). Effective inquiry-based instruction requires teachers to model scientific reasoning and encourage students to engage in critical thinking and problem-solving (Maeng et al., 2020).

In conclusion, while there is a general recognition among teachers of the importance of data analysis, laboratory skills, and reasoning in scientific inquiry, practical challenges hinder their effective implementation in the classroom. Continuous professional development and support are essential to equip teachers with the necessary skills and resources to foster inquiry-based learning effectively, ultimately enhancing students' scientific literacy and engagement (Pérez & Díaz-Moreno, 2022; Bioco & Echaure, 2021).

Collaboration in Inquiry-Based Learning

A majority of teachers understand that scientific inquiry encourages collaboration in solving scientific problems, with 62.3% agreeing and 27.9% strongly agreeing, while 8.2% somewhat disagreed and 1.6% disagreed. This indicates that many teachers recognize that science is not an isolated endeavor but rather a collaborative process, in which scientists work together to test ideas and share findings (Meilani & Faradiba, 2019). Thus, teachers who understand the importance of collaborative learning in science should encourage more group-based investigations and facilitate peer discussions where students can share their experimental results. Research emphasizes that collaborative inquiry not only enhances students' understanding of scientific concepts but also fosters essential skills such as communication and teamwork (Suárez et al., 2018; Nzomo et al., 2023).

Overall, science teachers possess a solid understanding of scientific inquiry, including its fundamental principles, instructional processes, essential skills, and the role of collaboration in science education. However, a gap persists between theoretical knowledge and classroom implementation, particularly regarding the effectiveness of inquiry-based learning. Many teachers remain uncertain about its application, likely due to time constraints, limited resources, and students' preparedness (Sypsas et al., 2020; Kinyota, 2023). To overcome these challenges, structured professional development programs are needed to help teachers build confidence in implementing inquiry-based learning. Additionally, improving access to laboratory resources and instructional materials that support inquiry-driven teaching is crucial (Mohammed & Amponsah, 2021; Deák et al., 2021).

Furthermore, collaboration among science teachers should be strengthened, allowing them to share best practices and successful strategies for implementing inquiry-based learning. With these initiatives in place, scientific inquiry-based instruction can be effectively integrated into science education, fostering students' critical thinking skills and a deeper understanding of scientific concepts (Cairns, 2019; Adeyele, 2023). The promotion of collaborative practices among educators is essential for creating a supportive environment where inquiry-based learning can thrive, ultimately benefiting student outcomes in science education (Pedaste et al., 2021; Alarcón et al., 2023)

Conclusion

In conclusion, the majority of science teachers have a strong understanding of the Nature of Science (NOS) and Nature of Scientific Inquiry (NOSI), including fundamental principles, the scientific method, and the importance of inquiry and collaboration in science education. However, a gap remains between conceptual understanding and classroom implementation, particularly in effectively applying inquiry-based learning models. The primary challenges include limited facilities, time constraints, and the readiness of both students and teachers to adopt inquiry-based approaches. To address these challenges, teacher training programs, improved laboratory facilities, and the development of more flexible and adaptive teaching strategies are essential. Additionally, collaboration among science teachers should be strengthened to enable experience-sharing and the exchange of best practices in implementing inquiry-based learning. By taking these steps, NOS- and NOSI-based approaches can be more effectively integrated into science education, allowing students to develop critical thinking, analytical skills, and a deeper understanding of scientific concepts.

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