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Identifying Prospective Physics Teachers' Understanding of Scientific Inquiry

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Abstract

This study aims to investigate the understanding of scientific inquiry among prospective physics teachers' and to identify any gaps between the procedural and philosophical aspects of inquiry. Understanding this profile is uniquely crucial for physics educators, as the discipline's heavy mathematical load often obscures the philosophical nature of science. This qualitative descriptive study involved 27 prospective physics teachers at Malang State University as respondents. The instrument used was the Views About Scientific Inquiry (VASI) questionnaire, which covers eight aspects of scientific inquiry. The analysis reveals a distinct procedural-epistemological gap. Based on the VASI rubric, all participants were categorized as informed on procedural aspects, including question-guided procedures, the impact of procedures on results, the consistency of conclusions with the data, and the synthesis of data with prior knowledge. Conversely, notable naive and mixed views emerged regarding philosophical aspects, particularly regarding the obligation of hypotheses, the myth of a single scientific method, and the role of subjectivity in data interpretation. These findings suggest that participants' prior laboratory experiences may have heavily emphasized technical verification practicums rather than epistemological reflection. Therefore, teacher education programs need to integrate an explicit, reflective instructional approach to the nature of scientific inquiry to equip prospective teachers with a comprehensive understanding of science before entering the professional world.

Keywords: Prospective physics teachers; understanding of scientific inquiry; VASI.

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INTRODUCTION

Physics is fundamentally a discipline built on the foundation of scientific inquiry, where knowledge is not merely a collection of mathematical formulas, but rather the result of a process of investigation involving observation, inference, and modeling of natural phenomena. Understanding how physics knowledge is obtained, often referred to as the epistemological aspect of science, is far more crucial than simply mastering laboratory procedures (Aditomo & Klieme, 2020; Koponen, 2007; Michel & Neumann, 2017). In the context of education, scientific inquiry should be viewed as two complementary entities: inquiry as a practical skill (doing inquiry) and inquiry as cognitive understanding (understanding about inquiry) (Lederman et al., 2013; Schwartz, R. S. et al, 2023). The inability to distinguish between the two often causes physics learning to be stuck in a mechanical "cookbook" laboratory, without giving students room to understand the tentative and creative nature of science (Abd-El-Khalick, 2012; Osborne, 2014; Wong & Hodson, 2010).

The role of physics teachers is crucial in determining how science is presented in the classroom. Teachers who have a naive conception of scientific inquiry tend to position themselves as the sole authority on truth and lead students to believe that science is absolute (Bartos & Lederman, 2014; Luehmann, 2007; Mesci & Schwartz, 2017). Conversely, prospective teachers with a mature understanding of scientific inquiry can facilitate critical discussions about the validity of data and the role of theory in guiding observation (Heron & Meltzer, 2005). However, a major challenge arises when prospective physics teachers themselves still carry misconceptions from their previous education. The view that "scientific research often begins with a hypothesis, not just a question" suggests an understanding that remains confined to a single, rigid scientific method (Gaigher et al., 2014; Gyllenpalm et al., 2010; Stylos et al., 2023).

The low levels of scientific inquiry understanding among students cannot be overcome without the readiness of teachers to teach these concepts in their lessons (Cigdemoglu, C. & Koseoglu, 2019). Teachers who have sufficient skills and understanding of scientific inquiry during their studies will tend to apply it in classroom learning (Baykara & Yakar, 2020). To map this pedagogical readiness theoretically, the *Views About Scientific Inquiry* (VASI) instrument has mapped eight key aspects that distinguish naive, mixed, and informed understandings of inquiry (J. Lederman et al., 2014). In physics education, the aspects of "procedures influence results" and "data is different from evidence" are very vital because the interpretation of graphs or digital data often requires a specific theoretical framework that may differ between individuals (Etkina, 2015; Koponen & Mäntylä, 2006; Wilcox & Lewandowski, 2016). Research on scientific inquiry understanding profiles has been conducted at various levels, but the results still show a worrying trend. Zahra & Anjani, (2025) In their study of prospective elementary school teachers in Indonesia, researchers found that the majority of participants were in the naive category, especially in understanding the need for consistency between conclusions and the data collected. Similar findings have also been reported in various countries, showing that higher education often focuses more on technical content than on the nature of science (Duschl & Grandy, 2013; Hofstein & Lunetta, 2004; Smith et al., 2000).

Despite extensive research on students' and teachers' understanding of scientific inquiry, studies focusing specifically on prospective physics teachers remain limited. A clearer distinction must be made between physics education and other science disciplines, such as biology or primary science education. In biology or primary education, the descriptive nature of the subjects often aligns more naturally with discussions on the Nature of Science (NOS). In contrast, physics entails a high mathematical cognitive load (Supeno et al., 2020). This unique disciplinary context frequently obscures the philosophical and epistemological understanding of inquiry, as students are conditioned to view laboratory practices merely as rigid mathematical verification of established formulas rather than as interpretive, theory-laden processes. Doubts about the absence of hypotheses and methodological diversity indicate a critical need for deeper conceptual intervention within this specific cohort (Bell et al., 2003).

Identifying patterns of understanding within this mathematically rigorous context is crucial to mapping the extent to which prospective physics teachers realize that science is an interpretive social activity, not merely the verification of formulas on paper (Erduran et al., 2018; Wong & Hodson, 2010). In fact, the current Merdeka Curriculum policy requires teachers to design authentic project-based learning, which is impossible without a solid understanding of scientific inquiry (Kemendikbudristek, 2022; Mundilarto, 2003). Without accurate identification of these conceptual barriers, physics education programs will struggle to determine the precise starting point for reforming practicum courses and research methodology (Faikhamta, 2013). To address this gap, this study aims to investigate prospective physics teachers' understanding of scientific inquiry and explicitly identify the epistemological gaps between the procedural and philosophical aspects of inquiry. The focus is on exploring the interpretive reasoning underlying participants' conceptions to determine their categories of understanding and highlight the most dominant misconceptions specific to the context of physics. The results of this study are expected to serve as empirical references for the development of a physics teacher education curriculum that emphasizes scientific literacy and the Nature of Science (NOS), ensuring that future teachers possess the epistemological wisdom to guide future generations (Hodson, 2014; Liang et al., 2008).

METHODS

This study uses a qualitative approach with a descriptive design to explore in depth prospective physics teachers' understanding of aspects of scientific inquiry (Creswell & Poth, 2016; M. Miles et al., 2013). The use of qualitative descriptive methods is considered appropriate because this study aims to capture the phenomenon of the subjects' thinking without intervention, as well as to present a narrative description of their categories of understanding based on the empirical evidence found (Fraenkel, J. R., et al, 2019; Zahra & Anjani, 2025). The participants were 27 prospective physics teachers enrolled in the Physics Learning (*Pembelajaran Fisika*) course at Universitas Negeri Malang. The participants were in their fifth semester. This demographic was purposely selected using a purposive sampling method. By the fifth semester, these students had completed multiple foundational and advanced physics laboratory courses, ensuring they possessed prior empirical laboratory experience and had been exposed to formal scientific investigations at the university level. This was intended to ensure that the data obtained reflected the understanding of students who had been exposed to formal inquiry activities at the university level (Supeno et al., 2020). The main instrument used was the *Views About Scientific Inquiry* (VASI) questionnaire developed by J. Lederman et al., (2014). This instrument consisted of eight open-ended questions designed to reveal eight aspects of scientific inquiry. To accommodate the participants, the original English questionnaire was translated into Indonesian. A forward-translation process was conducted, followed by a review by science education experts to ensure construct equivalence and terminology accuracy without altering the core meaning of the eight aspects.

Table 1. Aspects of scientific inquiry

No	Aspect	Question Number
1	Scientific investigations all begin with a question but do not necessarily test a hypothesis	1
2	There is no single set and sequence of steps followed in all scientific investigations (i.e., there is no single scientific method)	2
3	Inquiry procedures are guided by the question asked	3
4	All scientists performing the same procedures may not get the same results	4
5	Inquiry procedures can influence the results	5
6	Research conclusions must be consistent with the data collected	6
7	Scientific data are not the same as scientific evidence	7
8	Explanations are developed from a combination of collected data and what is already known	8

Data were collected via a digital platform (Google Forms) to make it easier for participants to provide in-depth written answers independently. During the completion process, participants were asked not to consult external references so that their answers reflected only their own conceptions. Participants' essay answers served as primary data, which were then verified to ensure that each argument addressed the essence of the scientific inquiry being measured (Bartos & Lederman, 2014; Schwartz, et al., 2023).

Data analysis was conducted using content analysis techniques, following the stages outlined by Miles & Huberman (1994) data reduction, data presentation, and conclusion drawing/verification. Each participant's answer was categorized into three levels of understanding based on the rubric developed by J. Lederman et al., (2014) namely (1) Informed, if the answer was in line with the currently accepted scientific view of inquiry, (2) *Mixed,* if the answer shows correct understanding but still contains elements of misconception or is incomplete, and (3) *Naïve*, if the answer is completely inconsistent with the principles of scientific inquiry or contains fundamental conceptual errors. To establish clear decision rules, particularly for ambiguous or overly short and irrelevant responses, the coders evaluated only the explicit written statements without inferring unwritten assumptions; any response lacking sufficient detail or clear alignment with the target aspect was conservatively categorized as Naive. To maintain the validity and reliability of the analysis results, the coding process was carried out collaboratively or through researcher triangulation, in which the research team analyzed the data independently and then discussed them until an agreement was reached (inter-rater reliability) (Creswell, 2014; Mesci & Schwartz, 2017).

Before collecting data, all participants were required to provide informed consent. They were also assured that their responses would be kept completely anonymous and would not have any negative impact on their course grades. This ethical safeguard was crucial in promoting honest and unfiltered answers, which ultimately enhanced the credibility of the primary data. Additionally, to ensure dependability and confirmability, the research team kept a detailed audit trail throughout the translation, data collection, and coding processes. This involved systematically documenting all translated excerpts and analytical decisions, allowing for cross-verification and ensuring that the final categorizations accurately reflected the participants' conceptual frameworks rather than the researchers' subjective biases.

RESULTS & DISCUSSION

Results

This study aims to identify prospective physics teachers' understanding of scientific inquiry. The analysis results for each of the eight aspects of scientific inquiry, categorized into Naive, Mixed, and Informed levels, are presented in Table 2. Because the sample size is relatively small (n=27), the data is presented using both frequency counts (n) and percentages (%) to provide a transparent representation of the distribution.

Table 2. Percentage of Scientific Inquiry Understanding

Aspect	Aspect Scientific Inquiry	Naive n (%)	Mixed n (%)	Informed n (%)
1	Scientific investigations all begin with a question but do not necessarily test a hypothesis	37% (10)	48% (13)	15% (4)
2	There is no single set and sequence of steps followed in all scientific investigations (i.e., there is no single scientific method)	7% (2)	48% (13)	45% (12)
3	Inquiry procedures are guided by the question asked	0% (0)	0% (0)	100% (27)
4	All scientists performing the same procedures may not get the same results	52% (14)	41% (11)	7% (2)
5	Inquiry procedures can influence the results	0% (0)	0% (0)	100% (27)
6	Research conclusions must be consistent with the data collected	0% (0)	0% (0)	100% (27)
7	Scientific data are not the same as scientific evidence	4% (1)	44% (12)	52% (14)
8	Explanations are developed from a combination of collected data and what is already known	0% (0)	0% (0)	100% (27)

The results of a study of 27 prospective physics teachers show varying profiles. Based on Table 2, the prospective physics teachers demonstrated a consistent "Informed" understanding across several procedural aspects of inquiry (Aspects 3, 5, 6, and 8), where all 27 participants (100%) met the criteria for the informed category. This uniform result aligns with their educational context; as fifth-semester students, they have completed numerous highly structured physics laboratory courses that strictly enforce these operational procedures. However, the data reveals significant variations and a tendency toward "Mixed" and "Naive" categories in the more philosophical aspects (Aspects 1, 2, 4, and 7). To facilitate a deeper and more structured analysis, the eight aspects of scientific inquiry evaluated by the VASI instrument were synthesized into three overarching thematic categories based on their epistemological similarities. To demonstrate how the rubric was applied to the open-ended responses, representative excerpts for the key findings are provided below.

Understanding of Procedural Aspects (Aspects 3, 5, 6, and 8)

All participants (100%) were categorized as informed in these four aspects. For instance, regarding Aspect 3 (procedures are guided by the question), participants clearly articulated the dependent relationship between research goals and methods. Participant NR's opinion, *"the research question served as the basis for the procedure,"* which is similar to AF's opinion that *"the procedure was necessary to guide the research and yield results aligned with the objectives"*. This response was coded as informed because it directly connects the research question to the experimental design. A similar pattern emerged for Aspect 6 (conclusions must be consistent with data), where participant OK illustrated an understanding of data authority: *"if the conclusions do not match the data, the research becomes invalid because researchers are obliged to report what the data actually shows, not what they want"*. This is reinforced by NE's explanation, *"conclusions from real data are crucial to avoid subjective bias"*. Meanwhile, AF sees this relationship as an absolute synchronization. *"Conclusions are the core of the entire research process* *and must accurately reflect the data obtained"*. These views show that students understand the role of conclusions as answers to empirically verified research questions. Furthermore, for Aspect 8 (explanations are developed from collected data and what is already known), participants demonstrated a mature ability to synthesize information. For example, participant BC stated, *"If we only use data, it will be too abstract, while if we only use knowledge, it will be too assumptive, so the two must be combined"* This indicates a strong grasp of how theoretical frameworks interact with empirical findings.

Understanding of the Role of Hypotheses (Aspect 1) and Methods (Aspect 2)

In Aspect 1, the majority of students fell into the mixed (48%) or naive (37%) categories. Naive responses demonstrated a rigid belief regarding the absolute necessity of hypotheses. A representative naive can be seen from NR's opinion, *"Scientific research often begins with a hypothesis, not just a question,"* which is similar to BC's opinion that *"without a hypothesis, research will be too broad and difficult to complete"*. Meanwhile, responses coded as 'Mixed' (48% in both Aspects 1 and 2) often acknowledged methodological variation but still insisted on a rigid procedural sequence. For example, regarding Aspect 2, participant EA stated, "There are many types of research, but all of them must follow the same systematic sequence of the scientific method." This response is mixed because it demonstrates partial understanding intertwined with traditional linear misconceptions. Conversely, the small informed minority (15%), such as participant AF, understood the flexibility of inquiry: *"the objectives of research in each scientific field differ, so there is no 'standard' sequence or series"*. Similarly, NR emphasized that methods can vary depending on the needs of the research.

Understanding of Subjectivity and Data Interpretation (Aspects 4 and 7)

Aspect 4 yielded the highest percentage of naive responses (52%). When asked why scientists might obtain different results from the same procedure, the majority attributed the variance purely to technical incompetence or human error rather than differences in interpretation. A typical naive response was "*everyone certainly has different skills,*" implying that differences in results stem from practitioners' inability to follow procedures precisely. Only a small fraction were categorized as informed by correctly identifying that researchers may hold different theoretical perspectives when interpreting data (theory-ladenness). Only a small fraction (7%) were categorized as informed by correctly identifying the theory-ladenness of observation. As participant AZ astutely noted, *"differences in results arise because each researcher has different thoughts and ways of interpreting the results."* This demonstrates a mature philosophical understanding of subjectivity. Additionally, Aspect 7 (scientific data vs evidence) revealed a sharp conceptual dynamic. While many reached the informed category, naive and mixed respondents failed to distinguish the two. For instance, a naive response from PS argued that *"scientific data and scientific evidence are the same because data necessarily contains evidence,"* erroneously treating data as an absolute truth rather than a component requiring intellectual intervention. Conversely, informed participant AF correctly delineated them, explaining that *"scientific data is raw data, while scientific evidence is data that has undergone research or processing to support a claim."*

Discussion

The findings of this study reveal a pronounced procedural-epistemological gap in prospective physics teachers' understanding of scientific inquiry. While the participants demonstrated an excellent capacity to operationalize inquiry procedures, this proficiency did not seamlessly translate into a comprehensive philosophical understanding of the Nature of Science (NOS). The participants demonstrated absolute cognitive maturity in understanding the procedural mechanisms of inquiry, specifically in recognizing that procedures are guided by research questions, that methodology influences results, and that conclusions must be strictly consistent with collected data. Students internalized the logic that experimental design is a strategic instrument acting as an intellectual compass (Gaigher et al., 2014). Furthermore, their awareness that explanations are developed from a combination of collected data and existing knowledge highlights a mature understanding of scientific synthesis, where theory serves as both a validation tool and a compass for interpreting raw data. This robust procedural understanding can be attributed to the specific epistemology of physics learning.

According to Duschl & Grandy (2013), Koponen & Mäntylä (2006) the ability to connect questions to procedures and theory is at the heart of scientific modeling. However, because physics education inherently carries a high mathematical cognitive load and heavily relies on highly structured verification practicums, students are intensively trained in variable control and mathematical precision (Abd-El-Khalick, 2012; Supeno et al., 2020). While this ensures they do not jump to conclusions without empirical support, it inadvertently conditions them to view laboratory work purely as the mechanical execution of established formulas, effectively mastering the "doing" of inquiry while neglecting the deeper "understanding" of it (Etkina, 2015). This interpretation is supported by an informal observation of the physics laboratory manuals used in their coursework, which predominantly feature step-by-step "cookbook" instructions aiming to verify established laws rather than facilitating open-ended inquiry.

This verification-oriented background fundamentally limits the prospective teachers' theoretical conceptualization of inquiry, particularly regarding the necessity of hypotheses and the diversity of scientific methods. A significant portion of the students held a dogmatic belief that hypotheses are an absolute requirement that cannot be abandoned. Arguments stating that without a hypothesis, research will be too broad reflect a heavy reliance on the linear representation of the Scientific Method, frequently oversimplified in traditional science textbooks, where the hypothesis is positioned as a mandatory procedural step (J. Lederman et al., 2014; Stylos et al., 2023). Although some informed students correctly noted that research methods are highly dependent on the scientific domain and can begin with pure observation, the majority remained caught in an ambiguity between methodological flexibility and procedural rigidity (Koponen, 2007; Zahra & Anjani, 2025). They acknowledged methodological variation but still stipulated that research must be conducted in a strictly systematic and sequential manner (Osborne, 2014). This limited perspective indicates that prospective teachers do not yet fully view scientific inquiry as a flexible, dynamic epistemological process. If these teachers continue to believe that linear steps and tentative answers are mandatory, they risk stifling students' scientific literacy and creativity in formulating authentic inquiry questions in their future classrooms (Heron & Meltzer, 2005).

The most critical epistemological barrier identified in this study is the subjectivity of data interpretation and the distinction between data and evidence. Many students in the study attributed differences in results from identical procedures to external factors, environmental influences, or individual psychomotor incompetence and human error. These responses reflect a lingering belief in positivism, which views science as an entirely objective process that is only disrupted by external variables or technical failures, rather than recognizing the inherent role of human interpretation. Only a small fraction of students in the study reached a more informed understanding by recognizing that researchers hold different theoretical perspectives when interpreting results. This highlights the epistemological core of science known as the theory-ladenness of observation (Wong & Hodson, 2010). Additionally, many students in the study failed to distinguish between raw data and functional evidence, mistakenly believing that data has intrinsic meaning that directly proves a truth without the need for intellectual intervention. This lack of differentiation between data and evidence can hinder the construction of strong scientific arguments. If prospective teachers bring this positivist mindset into the classroom, they may be more likely to blame students' incompetence when experimental results deviate from textbook theories, rather than encouraging critical discussion of the logical and interpretative reasons for data variation.

Furthermore, the persistence of these epistemological misconceptions cannot be separated from the prevailing assessment paradigms in traditional physics education. Historically, physics assessments at the university level heavily prioritize quantitative problem-solving and the ability to derive exact mathematical answers. When high-stakes exams consistently reward absolute numerical precision and single correct answers, students are indirectly conditioned to view science as an exact, deterministic enterprise rather than a tentative, interpretive process. This assessment-driven learning environment reinforces the positivist paradigm observed in the participants' responses, particularly their tendency to attribute data variations merely to 'human error' rather than theoretical differences. Therefore, addressing the procedural-epistemological gap requires more than just changing instructional methods; it requires a fundamental shift in how prospective teachers are evaluated. Teacher educators must begin incorporating qualitative assessments that evaluate scientific argumentation, the ability to critique experimental designs, and the capacity to articulate the Nature of Science (NOS), ensuring that epistemological wisdom is valued as highly as procedural execution.

These findings reinforce the urgency of explicitly teaching the nature of science in higher education. As Bartos & Lederman, (2014) emphasized, without an understanding of methodological diversity and subjectivity, teachers tend to simplify inquiry into mere laboratory activities, ultimately distancing students from actual scientific practice. To produce physics teachers who are not only technically competent but also possess epistemological wisdom, university curricula must integrate explicit-reflective NOS instruction (N. Lederman & Lederman, 2019). Traditional verification laboratories must be redesigned to include structured NOS reflection prompts, data versus evidence discussions, and argumentation rubrics, ensuring that future educators can facilitate authentic, interpretive science learning (Adisendjaja et al., 2016; Stott & Hattingh, 2020). In the context of Indonesia's current Merdeka Curriculum, which strongly advocates for authentic project-based learning, addressing this epistemological vulnerability is critical. If prospective teachers view data merely as absolute numbers rather than interpreted evidence, they will struggle to facilitate the open-ended, problem-solving projects mandated by the new national curriculum.

CONCLUSION

This study suggests that prospective physics teachers have a strong understanding of the practical aspects of scientific inquiry, as shown by their consistent alignment with the VASI rubric’s informed categories. However, there is a significant gap in thier understanding of philosophical aspects of science, such as the importance of hypotheses, the variety of scientific methods, and the subjectivity of data interpretation. This indicates that the current physics teacher education curriculum may place too much emphasis on verification-oriented laboratory practicums, which can inadvertently obscure the critical, reflective nature of authentic scientific inquiry. Therefore, it is crucial to reform the curriculum in physics teacher education programs. It is highly recommended to incorporate explicit and reflective instruction on the Nature of Science (NOS) into core pedagogy and laboratory courses. This will better prepare prospective teachers will be better equipped to translate mechanical laboratory exercises into meaningful, inquiry-based scientific practices for their future students. Future research should focus on longitudinal studies to assess the effectiveness of these NOS interventions across different scientific disciplines and wider institutional contexts.

LIMITATIONS

While this study provides valuable insights into the epistemological profiles of prospective physics teachers, several limitations must be explicitly acknowledged to ensure balanced interpretations and curricular recommendations. First, the sample size was relatively small, comprising only 27 participants from a single institution, which naturally limits the broad generalizability of the findings across diverse educational contexts. Second, the data collection relied exclusively on written self-reports administered through a digital questionnaire. Although the open-ended nature of the VASI instrument allows for qualitative depth, this method does not capture the participants' real-time classroom practices or their pedagogical decision-making processes in actual teaching environments. Therefore, the interpretations drawn and the subsequent recommendations for curriculum reform should be viewed as a foundational empirical reference rather than a definitive, universal framework.

REFERENCES

Abd-El-Khalick, F. (2012). Examining the Sources for our Understandings about Science: Enduring conflations and critical issues in research on nature of science in science education. *International Journal of Science Education*, *34*(3), 353-374. https://doi.org/10.1080/09500693.2011.629013

Adisendjaja, Y. H., Rustaman, N., Redjeki, S., & Satori, D. A. (2016). Gambaran Pandangan Mahasiswa Calon Guru Biologi dan Guru IPA tentang Inkuiri Ilmiah. *Jurnal Pengajaran Matematika dan Ilmu Pengetahuan Alam*, *21*(1), 73-81. https://doi.org/10.18269/jpmipa.v21i1.36260

Aditomo, A., & Klieme, E. (2020). Forms of inquiry-based science instruction and their relations with learning outcomes: evidence from high and low-performing education systems. *International Journal of Science Education*, *42*(4), 504-525. https://doi.org/10.1080/09500693.2020.1716093

Bartos, S., & Lederman, N. (2014). Teachers' Knowledge Structures for Nature of Science and Scientific Inquiry: Conceptions and Classroom Practice. *Journal of Research in Science Teaching*, *51(9)*. https://doi.org/10.1002/tea.21168

Baykara, H., & Yakar, Z. (2020). *Preservice Science Teachers ' Views about Scientific Inquiry : The Case of Turkey and Fen Öğretmen Adaylarının Bilimsel Araştırmaya Yönelik Görüşleri : Türkiye ve Tayvan Örneği Öz. 11*(2), 161–192. https://doi.org/10.17569/tojqi.618950

Bell, R., Blair, L., Crawford, B., & Lederman, N. (2003). Just do it? Impact of a science apprenticeship program on students' understanding of the nature of science and scientific inquiry. *Journal of Research in Science Teaching*, *40*(5), 487–509. https://doi.org/10.1002/tea.10086

Campanile, M., Lederman, N., & Kampourakis, K. (2013). Mendelian Genetics as a Platform for Teaching About Nature of Science and Scientific Inquiry: The Value of Textbooks. *Science & Education*, *24*(1). https://doi.org/10.1007/s11191-013-9607-4

Cigdemoglu, C. & Koseoglu, F. (2019). Improving Science Teachers' Views about Scientific Inquiry: Reflections from a Professional Development Program Aiming to Advance Science Centre-School Curricula Integration. *Science & Education*, *28*(3–5), 439–469. https://doi.org/10.1007/s11191-019-00054-0

Creswell, J. W., & Poth, C. N. (2016). *Qualitative inquiry and research design: Choosing among five approaches*. Sage publications.

Duschl, R., & Grandy, R. (2013). Two Views About Explicitly Teaching Nature of Science. *Science & Education*, *22*(1). https://doi.org/10.1007/s11191-012-9539-4

Erduran, S., Kaya, E., & Dagher, Z. R. (2018). From Lists in Pieces to Coherent Wholes: Nature of Science, Scientific Practices, and Science Teacher Education. *BT - Science Education Research and Practice in Asia-Pacific and Beyond*, *10*(2), 3-24. https://doi.org/10.1007/978-981-10-5149-4_1

Etkina, E. (2015). Millikan award lecture: Students of physics—Listeners, observers, or collaborative participants in physics scientific practices? *American Journal of Physics*, *83*(8), 669–679. https://doi.org/10.1119/1.4923181

Faikhamta, C. (2013). The Development of In-Service Science Teachers' Understandings of and Orientations to Teaching the Nature of Science within a PCK-Based NOS Course. *Research in Science Education*, *43*(4), 847–869. https://doi.org/10.1007/s11165-012-9283-4

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2019). How to design and evaluate research in education (10th ed.). *McGraw-Hill Education*.

Gaigher, E., Lederman, N., & Lederman, J. (2014). Knowledge about Inquiry: A study in South African high schools. *International Journal of Science Education*, *36*(18), 3125–3147. https://doi.org/10.1080/09500693.2014.954156

Gyllenpalm, J., Wickman, P.-O., & Holmgren, S. (2010). Teachers' Language on Scientific Inquiry: Methods of Teaching or Methods of Inquiry?. *International Journal of Science Education*, *32*(9), 1151-1172. https://doi.org/10.1080/09500690902977457

Heron, P., & Meltzer, D. (2005). The future of physics education research: Intellectual challenges and practical concerns. *American Journal of Physics*, *73*(4), 390-394. https://doi.org/10.1119/1.1858480

Hodson, D. (2014). Learning Science, Learning about Science, Doing Science: Different goals demand different learning methods. *International Journal of Science Education*, *36*(15), 2534-2553. https://doi.org/10.1080/09500693.2014.899722

Hofstein, A., & Lunetta, V. (2004). The Laboratory in Science Education: Foundations for the Twenty-First Century. *Science Education*, *88*(1), 28-54. https://doi.org/10.1002/sce.10106

Kemendikbudristek. (2022). *Kurikulum untuk Pemulihan Pembelajaran*. Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi.

Koponen, I. (2007). Models and Modelling in Physics Education: A Critical Re-analysis of Philosophical Underpinnings and Suggestions for Revisions. *Science & Education*, *16*(1), 751–773. https://doi.org/10.1007/s11191-006-9000-7

Koponen, I., & Mäntylä, T. (2006). Generative Role of Experiments in Physics and in Teaching Physics: A Suggestion for Epistemological Reconstruction. *Science & Education*, *15*(1), 31–54. https://doi.org/10.1007/s11191-005-3199-6

Lederman, J., Lederman, N., Bartos, S., Bartels, S., Antink-Meyer, A., & Schwartz, R. (2014). Meaningful Assessment of Learners' Understandings About Scientific Inquiry-The Views About Scientific Inquiry (VASI) Questionnaire. *Journal of Research in Science Teaching*, *51*(1), 65-83. https://doi.org/10.1002/tea.21125

Lederman, N. G., Lederman, J. S., Nature, A., Lederman, N. G., Lederman, J. S., & Antink, A. (2013). Nature of Science and Scientific Inquiry as Contexts for the Learning of Science and Achievement of Scientific Literacy. *International Journal of Education in Mathematics, Science and Technology (IJEMST)*, *1*(3), 138-147. https://doi.org/10.46328/ijemst.v1i3.10

Lederman, N., & Lederman, J. (2019). Teaching and Learning of Nature of Scientific Knowledge and Scientific Inquiry: Building Capacity through Systematic Research-Based Professional Development. *Journal of Science Teacher Education*, *30*(7), 737-762. https://doi.org/10.1080/1046560X.2019.1625572

Liang, L., Chen, S., Xian, C., Adams, A., & Monica, M. (2008). Assessing preservice elementary teachers' views on the nature of scientific knowledge:A dual-response instrument. *Asia-Pacific Forum on Science Learning and Teaching*, *9*(1), 1-20. https://www.eduhk.hk/apfslt/v9_issue1/liang/index.htm

Luehmann, A. (2007). Identity development as a lens to science teacher preparation. *Science Education*, *91*(5), 822–839. https://doi.org/10.1002/sce.20209

Mesci, G., & Schwartz, R. (2017). Changing Preservice Science Teachers' Views of Nature of Science: Why Some Conceptions May be More Easily Altered than Others. *Research in Science Education*, *47*(4), 329-351. https://doi.org/10.1007/s11165-015-9503-9

Michel, H., & Neumann, I. (2017). Nature of Science and Science Content Learning: The Relation Between Students' Nature of Science Understanding and Their Learning About the Concept of Energy. *Science & Education*, *25*(1), 951-975. https://doi.org/10.1007/s11191-016-9860-4

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. Sage publications.

Miles, M., Huberman, M., & Saldaña, J. (2013). Qualitative Data Analysis: A Methods Sourcebook. Sage publications.

Mundilarto, M. (2003). Membangun Karakter Melalui Pembelajaran Sains. *Jurnal Pendidikan Karakter, 20*(1), 153–163. https://doi.org/10.21831/jpk.v2i2.1436.

Osborne, J. (2014). Teaching Scientific Practices: Meeting the Challenge of Change. *Journal of Science Teacher Education*, *25*(2), 177-196. https://doi.org/10.1007/s10972-014-9384-1

Schwartz, R. S., Lederman, J. S., & Enderle, P. J. (2023). Scientific Inquiry Literacy. In Handbook of Research on Science Education. *Routledge*, *3*(4), 749–782. https://doi.org/10.4324/9780367855758-28

Smith, C., Maclin, D., Houghton, C., & Hennessey, M. (2000). Sixth-Grade Students' Epistemologies of Science: The Impact of School Science Experiences on Epistemological Development. *Cognition and Instruction - COGNITION INSTRUCT*, *18*(3), 349–422. https://doi.org/10.1207/S1532690XCI1803_3

Stott, A., & Hattingh, A. (2020). Pre-service teachers' views about the nature of science and scientific inquiry: The South African case. *South African Journal of Education*, *40*(1),51-86 . https://doi.org/10.15700/saje.v40n1a1573

Stylos, G., Christonasis, A., & Kotsis, K. (2023). Pre-service Primary Teachers' Views about Scientific Inquiry. *International Journal of Studies in Education and Science*, *4*(2), 100–112. https://doi.org/10.46328/ijses.66

Supeno, S., Astutik, S., & Lesmono, A. (2020). Pre-service science teachers' understanding of scientific method for studying local environmental issues. *IOP Conference Series: Earth and Environmental Science*, *485*(1), 1-6. https://doi.org/10.1088/1755-1315/485/1/012033

Wilcox, B., & Lewandowski, H. (2016). Research-Based Assessment of Students' Beliefs about Experimental Physics: When is Gender a Factor?. *Physical Review Physics Education Research*, *12*(2), 1-11. https://doi.org/10.1103/PhysRevPhysEducRes.12.020130

Wong, S. L., & Hodson, D. (2010). More from the Horse's Mouth: What scientists say about science as a social practice. *International Journal of Science Education*, *32*(11), 1431–1463. https://doi.org/10.1080/09500690903104465

Zahra, I. R., & Anjani, N. (2025). Identifikasi Pemahaman Calon Guru SD Mengenai Inkuiri Ilmiah. *Jurnal Pendidikan MIPA*, *15*(2), 793–802. https://doi.org/10.23960/jpmipa.v26i1.30605