Understanding the Nature of Science (NoS) for Elementary School Students Based on Gender

Julia Anis Handayani[1*], Candra Tri Utami[2], Tia Citra Bayuni[3], Aan Yuliyanto[4]

[1,2,3,4]Elementary School Teacher Education, Universitas Pelita Bangsa, Indonesia

***Corresponding Author**

DOI: https://dx.doi.org/10.47772/IJRISS.2025.91100397

Received: 26 November 2025; Accepted: 04 December 2025; Published: 12 December 2025

ABSTRACT

This research examines elementary school students' understanding of the Nature of Science (NoS) based on gender. The purpose of this study is to identify and analyse the level of understanding of male and female students regarding NoS concepts, which are an important foundation in science learning. This study uses a descriptive quantitative approach with a survey method to obtain students' understanding of NoS. The sampling technique was carried out through purposive sampling by considering certain characteristics relevant to the research objectives. The research sample consisted of upper elementary school students in the West Java region. The research instrument was a questionnaire containing 47 positive and negative statements with a Likert scale based on the components of NoS, namely scientific knowledge, scientific process, and scientific attitude, which had been developed through literature review and expert validation to explore students' understanding of various aspects of NoS. The results showed that male students obtained an average score of 66, while female students obtained an average score of 65. The difference between these figures was very small, indicating that there was no significant difference in NoS understanding between male and female students. These findings show that NoS understanding is not determined by gender. This study has limitations because it only focused on one region, so the results do not reflect the broader situation. Therefore, further research is recommended to be conducted with a larger geographical coverage and considering other categories such as interests, place of residence, class level, profession and other categories. With a broader research coverage, a more comprehensive reprecentation of students' understanding of NoS in Indonesia is expected to be obtained.

Keywords: Elementary School Students, Gender, Nature of Science

INTRODUCTION

Survey data from the Trends in International Mathematics and Science Study (TIMSS) conducted in 2015 shows that Indonesian students' science scores ranked 44th out of 47 countries surveyed. TIMSS is a project developed by the International Association for the Evaluation of Educational Achievement (IEA), which has been a pioneer in international comparative studies since 1995, focusing on evaluating the mathematics and science skills of students in grades 4 and 8, although in 2015 data was only collected from grade 4 elementary school students. TIMSS is conducted periodically every four years, with questionnaires covering aspects of students' home and school life, including basic demographic information, home environment, school climate, and self-perception and attitudes towards mathematics and science learning. Indonesia has been involved since 2003 until 2015, with scores continuing to decline (Hamzah, 2023). These results indicate that students' mastery of concepts and understanding in the field of science is still weak. One of the factors contributing to these low achievements is students' lack of understanding of the Nature of Science (NoS).

Understanding NoS is a standard for passing science education before entering the next level (Amador-Rodríguez et al., 2021; Dogan & Abd-El-Khalick, 2008). NoS helps students understand how science and scientists work, as well as how scientific knowledge is generated, proven, and influenced. Understanding NoS is important because it can improve science literacy when dealing with various problems, especially those related to socio-scientific issues, so that logical solutions can be found (McComas, 2015).

Recognising the urgency of NoS at the elementary school level provides a strong foundation for further study on the level of student understanding in the early stages of formal education. Understanding NoS from an early age is expected to equip students to develop better scientific literacy at the next level of education (Adibelli-Sahin & Deniz, 2017; Almeida et al., 2023). NoS explains how a person acquires knowledge and understands scientific concepts correctly through orderly steps to produce appropriate findings (Lorsbach et al., 2019). This will ultimately empower students to think critically, make appropriate decisions, and engage with science issues in everyday life.

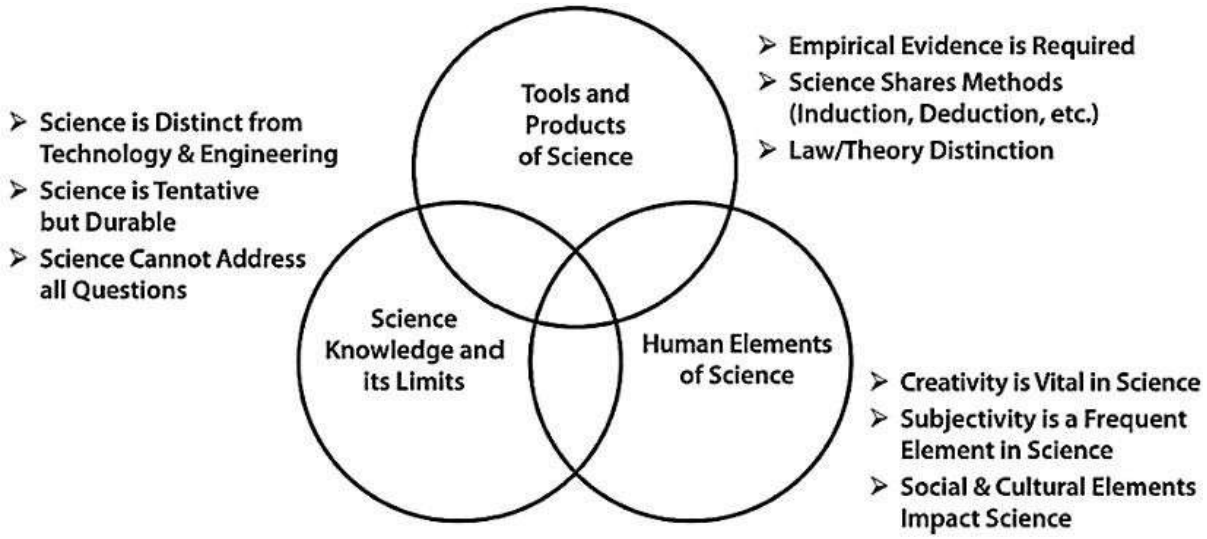
Given the importance of understanding NoS, it is necessary to conduct research to reveal the level of understanding of NoS, especially among elementary school students. Through this research, educators and policymakers can determine the current state of students' understanding of NoS. The data obtained will help identify areas that need improvement in learning, thereby providing a basis for developing more appropriate curricula and teaching strategies (Jiang & McComas, 2014; Yanuar & Widodo, 2020). For example, if a gap in understanding is found, the concept of NoS can be better integrated into science lessons so that students not only know scientific facts but also understand how science works as an investigative process and its role in society. With this research, the level of students' understanding of NoS can be determined through appropriate measurement tools. This study aims to determine the level of elementary school students' understanding of NoS based on gender. Although in several studies, no differences in cognitive abilities based on gender were found (Adiastuty et al., 2020; Hisanah et al., 2025; Siswati et al., 2016). This study remains important to provide an empirical description of the profile of elementary school students' understanding of NoS. It is hoped that the results of this study can be used as a reference in designing more optimal and planned science learning strategies to improve students' understanding of NoS.

LITERATURE REVIEW

Nature of Science

In science education, students are not only required to master scientific concepts and facts, but also to understand how scientific knowledge is formed. This understanding is known as the Nature of Science (NoS). NoS plays an important role because it provides an overview that science is an investigative process involving evidence, creativity, and is influenced by various social and cultural factors (Atakan & Akçay, 2022). Understanding NoS not only helps students comprehend the content of science, but also scientific ways of thinking and working. Understanding NoS helps students appreciate the beauty of nature and the role of science in improving human life. Thus, NoS is not merely scientific knowledge, but also a way to understand and appreciate the surrounding environment (Widodo, 2021).

Fig 1. The major elements of NOS appropriate for inclusion in science instruction, arranged in three related clusters (McComas, 2015)



.

NoS continues to attract the attention of experts, leading to differing opinions. Some experts divide NoS into several components, including empirical base, tentative theories and law, socio-cultural embeddedness, creativity, scientific method, and subjectivity (McComas, 2015). Others argue that NoS consists of empirical base, tentative theories and law, socio-cultural embeddedness, creativity, scientific method, and subjectivity (Lederman et al., 2002); empirical basis, tentative, theories and law, socio-cultural embeddedness, creativity, scientific method, subjective, cannot answer all questions, science and technology are not the same, and distinction between observation and inference (Alshamrani, 2008); empirical basis, tentative, socio-cultural embeddedness, creativity, scientific method, subjective, cannot answer all questions (Jiang & McComas, 2014); tentative, theories and law, socio-cultural embeddedness, creativity, scientific method, subjective, distinction between observation and inference (Temel et al., 2018).

However, science essentially comprises three components, namely scientific knowledge, scientific process, and scientific attitude, each of which has its own characteristics (Widodo, 2021). The relationship between these components can be seen in Table 1.

Table 1 The Relationship Between The Nature Of Science From A Component Point Of View And Its Nature Of Science

Science Component	Characteristic					
	Tentative	**Subjective**	**Empirical**	**Scientific Method**	**Limitations**	**Social Culture**
Knowledge	√	√	√			√
Process				√	√	
Attitude				√		

Table 1 shows that science encompasses not only scientific knowledge, but also the ways or methods of acquiring that knowledge, known as the scientific process. In addition, there is also the aspect of scientific attitude, namely the values and behaviours required in acquiring scientific knowledge. Thus, scientific knowledge is the result produced by scientists and is referred to as science as a product, while the method of acquiring knowledge is referred to as science as a process, and the values or attitudes that support the acquisition of knowledge are known as scientific attitudes (Kapsala et al., 2022).

Based on the table, it can be seen that scientific knowledge has four characteristics, including tentative, subjective, empirical, and socio-cultural. Furthermore, the scientific process has two characteristics, including scientific methods and limitations, while scientific attitudes only have one characteristic, namely using scientific methods. These three components with six characteristics form the core of NoS (Cahyana, 2025; Hayati Rahayu et al., 2019; Tursinawati & Widodo, 2019). These six characteristics form the basis for the development of a measuring instrument aimed at determining students' understanding of NoS. By including indicators for each characteristic in the instrument, researchers can assess the extent to which elementary school students understand the important aspects of NoS. The process of developing this instrument includes the preparation of questions that represent each characteristic.

METHODOLOGY

Research Design

This study utilised a quantitative method with a survey type of research aimed at obtaining information regarding the understanding of NoS among elementary school students based on gender. Data was obtained directly from respondents through a research instrument in the form of a questionnaire distributed via Google Forms. This study utilised descriptive statistical analysis to describe the understanding of NoS among elementary school students based on gender.

Population and Sample

The population in this study were elementary school students in West Java, Indonesia. The sample in this study consisted of 74 upper-grade elementary school students, comprising 37 female students and 37 male students. The data collection technique used was purposive sampling, which was selected based on specific considerations and objectives (Widodo et al., 2019). The consideration for selecting these students was that they had already begun to learn about the scientific process, simple experiments, and how science works in everyday life, making them suitable for measuring NoS indicators. At the upper grade level, students are already in the concrete operational stage towards the formal stage, so they are able to understand concepts, make logical assessments, and respond to research instruments in the form of questionnaires and tests more accurately. This research was conducted by providing NoS instruments in the form of questionnaires to the sample through Google Forms distributed by teachers at school. From these statements, students were asked to respond according to their understanding.

Research Instruments

Instrument development through three stages. The first stage involved conducting a literature review of NoS components from various experts by comprehensively examining the literature. The literature obtained NoS components including scientific knowledge (scientific products), scientific processes (scientific methods) and scientific attitudes (Widodo, 2021). The instrument was in the form of a questionnaire with 47 items in the form of statements developed from three components and seven characteristics/properties of NoS. The statements developed were positive and negative in nature, using a 4-point Likert scale, namely (1) Strongly disagree, (2) Disagree, (3) Agree, (4) Strongly agree. This scoring applies if the statement is positive; if the statement is negative, the opposite applies. In the second stage, the questionnaire items were developed and tested by experts. In the third stage, the NoS instrument was tested on primary school students. In this trial, respondents reviewed the content and language format, then reviewed the validity and reliability of the statement items. The validity and reliability of the instrument were measured using SPSS, which showed that the statement items were valid with $r_{calculated} > r_{table}$ (0.2242). The reliability calculation showed that the $r_{calculated}$ (0.66) > 0.60. Table 2 below is the NoS comprehension questionnaire grid.

Table 2 Nos Questionnaire

	Component	Aspect	Item	Amount
	Knowledge	Tentative	1, 2, 3, 4, 5, 6	6
		Subjective	7, 8, 9, 10, 11, 12	6
		Empiric	13, 14, 15, 16, 17, 18, 19	7
		Social culture	20, 21, 22, 23, 24, 25	6
	Process	Scientific method	26, 27, 28, 29, 30, 31, 32	7
		Limitations	33, 34, 35, 36, 37, 38, 39	7
	Attitude	Scientific method	40, 41, 42, 43, 44, 45, 46, 47	8
Amount				47

Data Analysis Techniques

Analysis of respondents' responses obtained through questionnaires was carried out in several steps. First, the questionnaire results were grouped based on negative and positive statements, then scored and totalled. After that, the total score was converted into a percentage scale so that it could be compared between aspects. The percentages obtained were then analysed descriptively by adjusting them to the predetermined assessment categories, namely very good, good, enough, bad and very bad. The assessment categories can be seen in Table

Further analysis was conducted by describing the scores obtained by students in understanding NoS based on gender. The scores are described, summarised, and linked to previous research conducted by other researchers.

Table 3 Percentage Of Criteria For Understanding Science

Percentage (%)	Criteria
84 – 100	Very Good
68 – 83	Good
52 – 67	Enough
36 – 51	Bad
< 36	Very Bad

(Jumanto & Widodo, 2018)

RESULTS AND DISCUSSION

This survey research was conducted simultaneously on male and female elementary school students. The following are the results of the NoS comprehension study based on gender. Based on the results of the Kolmogorov-Smirnov normality test, the data has a significance value of 0.200, so it can be concluded that the data is normally distributed. This indicates that further analysis using parametric tests, such as the independent samples t-test, can be carried out appropriately.

The results of the descriptive analysis show that the average NoS comprehension score for male students is 122.77, while female students have an average of 121.10. In terms of numbers, male students appear to have slightly higher comprehension scores than female students, but the difference is relatively small. The standard deviation of the two groups is also almost the same, so that the variation in data between groups does not show any significant differences. Furthermore, the results of the independent samples t-test show that the significance value (Sig. 2-tailed) is 0.270, which is greater than the $\alpha = 0.05$ limit. This means that there is no statistically significant difference between the levels of NoS comprehension of male and female students. This finding is reinforced by a mean difference value of 1.671, which is still within the confidence interval range that crosses zero, indicating that the difference is not inferentially meaningful.

Overall, despite minor differences in average scores, the analysis shows that gender does not significantly affect students' understanding of the Nature of Science (NoS). Thus, both male and female students demonstrate a relatively equal level of understanding of NoS. For further clarification, aspects of students' NoS are presented in Table 4 in percentage form.

Table 4 Percentage Nature Of Science

Category		Percentage (%)			
		Female	Criteria	Male	Criteria
Knowledge	Tentative	61	Enough	64	Enough
	Subjective	62	Enough	60	Enough
	Empiric	70	Good	67	Enough
	Social culture	64	Enough	63	Enough
Process	Scientific method	68	Good	71	Good
	Limitations	61	Enough	63	Enough

Category		Percentage (%)			
		Female	Criteria	Male	Criteria
Knowledge	Scientific method	66	Enough	68	Good
Amount		65	Enough	66	Enough

Based on Table 4, which shows primary school students' understanding of the NoS by gender, it can be seen that both male and female students show relatively similar patterns of understanding in most aspects of NoS. The results of the study indicate that the empirical aspect is the aspect of NoS that is most easily understood by students, regardless of gender. This is in line with research (Suratmi & Widodo, 2021) which shows that empirical results are one of the most valuable components. This can be explained because science learning in primary schools is still dominated by observation activities, simple experiments, and the use of concrete evidence (Nugraheny & Widodo, 2021). These types of activities help students understand that science is based on observational data.

Conversely, aspects such as tentative and subjective require an abstract understanding of the nature of scientific knowledge and how a person influences the scientific process. Meanwhile, socio-cultural aspects and limitations are often underemphasised in learning, and the limitations of the scientific method are difficult to understand without repeated investigative experience (Hardianty, 2015).

The finding that the differences between male and female students are very small supports previous research that understanding NoS at the primary school level is more influenced by learning experiences than by biological characteristics or gender. Small differences in scientific attitude scores are also within reasonable limits and do not show a significant influence. This shows that both female and male students only understand some aspects of NoS. This finding is in line with research conducted on elementary school students, which shows that the level of understanding of NoS is still in the enough category (Tursinawati & Widodo, 2019). It is undeniable that students' understanding of NoS equips them with essential skills in science. This becomes particularly relevant when students encounter everyday situations, including socio-scientific issues related to scientific concepts. In this context, basic skills in science education will naturally support students to use their scientific reasoning consistently (Khishfe, 2017).

Referring to the data obtained, even though they are in the same range, there are differences in the percentage of students' understanding of NoS based on gender. These differences in the characteristics of male and female students can be one of the factors in the acquisition of NoS understanding, even though the differences are not significant. As stated, factors such as misunderstandings, classroom rules, students' prior knowledge, and teachers' experiences can contribute to these differences (Hacieminoglu, 2014). Furthermore, other studies have found that teachers' understanding of NoS has an impact on their students' understanding of NoS (Kinskey, 2023; Widodo et al., 2019).

However, the findings of this study confirm that there is no difference in NoS understanding between male and female students in West Java. This is in line with studies conducted in different regions such as Kalimantan, West Nusa Tenggara, and Sulawesi, which show similar results that there are no significant differences in NoS understanding based on gender. These findings indicate that both male and female students have relatively equal opportunities and abilities in understanding NoS concepts. These results also reinforce the view that learning environment factors, learning quality, and access to learning resources have a greater influence than gender differences themselves (Jufri et al., 2025; Setya Novanto et al., 2021; Utami & Anitra, 2020). Thus, efforts to improve NoS understanding should focus on improving learning strategies and equitable educational support. As mentioned, there is a relationship between teaching styles and strategies in improving student learning outcomes (Go & Quicho, 2023).

Science education in schools, especially at the elementary level, requires a clearly designed approach that is linked to real-world contexts because NoS concepts will be more effectively understood if taught through

explicit and reflective learning, rather than implicitly by simply providing experiences of scientific activities (William F. McComas, 2017). Through specific interventions, elementary school teachers can improve understanding of NoS through explicit and reflective approaches (Chaiyabang & Thathong, 2014). This reflective approach emphasizes that understanding of NoS must be taught directly, rather than assumed to arise automatically during the learning process. Developments in the form of scientific history stories and the use of laboratories can be supportive in helping students understand how science works (Anane & Lomotey, 2023), and integrating technology-based learning can enhance critical and collaborative thinking in science understanding (Savira & Bahij, 2025; Tursinawati & Widodo, 2019). Another way to strengthen NoS in students is through discussion activities, investigative experiments, and uncovering socio-scientific issues (Adi & Widodo, 2018). For this reason, facilities and infrastructure are one of the elements needed to support students' understanding of NoS (Cahyana, 2025). Thus, improving the quality of science learning should focus on strengthening these aspects, not on gender differences among students.

CONCLUSION

Understanding NoS plays an important role in science learning in elementary school, as it helps students recognize how scientific knowledge, scientific processes, and scientific attitudes are constructed, validated, and used in everyday life. This understanding not only supports the mastery of scientific concepts, but also fosters scientific thinking, reasoning skills, and problem-solving skills. The results of the study show that there is no difference in understanding NoS between male and female students. This finding indicates that each gender has relatively equal opportunities and abilities in understanding NoS concepts. The absence of gender-based differences also confirms that the ability to understand NoS is not inherent in certain biological characteristics but is more influenced by the learning experiences gained by students. Furthermore, these results reinforce the view that learning environment factors, the quality of learning strategies, teaching styles, and the availability of learning resources have a much greater influence than student gender. Therefore, efforts to improve NoS understanding should focus on strengthening the quality of learning, teachers' understanding of NoS, and equal access to learning facilities and infrastructure. With improvements in these factors, students' understanding of NoS can increase more evenly and sustainably.

The results of this study have important implications for science education in primary schools, particularly in the development of understanding of NoS. The finding that empirical aspects and scientific methods are easier for students to understand shows that learning based on concrete activities and simple experiments has had a positive impact. However, the low level of understanding of tentative, subjective, socio-cultural aspects and limitations confirms that abstract concepts in NoS are still not being taught explicitly. Therefore, teachers need to design learning that not only focuses on practical activities, but also provides space for discussion, reflection, and scientific case studies that show how scientific knowledge can change, be influenced by the scientist's background, and be closely related to the socio-cultural context. Investigative activities that highlight the imperfection of data are also important for students to understand the limitations of the scientific method. Furthermore, as no significant differences were found between male and female students, teachers can apply the same learning strategies without the need for gender-based differentiation. Learning should emphasise the development of scientific processes, scientific attitudes, and critical reasoning that can strengthen the overall understanding of NoS for all students. These results also encourage schools and policymakers to provide support in the form of teacher training and the provision of experimental facilities that can enrich the science learning experience.

REFERENCES

1. Adi, Y. K., & Widodo, A. (2018). Pemahaman Hakikat Sains Pada Guru dan Siswa Sekolah Dasar. Edukasi Journal, 10(1), 55–72. https://doi.org/10.31603/EDUKASI.V10I1.1831
2. Adiastuty, N., Waluya, S. B., Junaedi, I., Masrukan, M., & Putri, C. M. (2020). Prosiding Seminar Nasional Pascasarjana Pengaruh Gaya Kognitif dan Gender Terhadap Kemampuan Berpikir Kreatif Matematis Siswa. 756–764. http://pps.unnes.ac.id/pps2/prodi/prosiding-pascasarjana-unnes
3. Adibelli-Sahin, E., & Deniz, H. (2017). Elementary teachers' perceptions about the effective features of explicit-reflective nature of science instruction. International Journal of Science Education, 39(6), 761–

790. https://doi.org/10.1080/09500693.2017.1308035
4. Almeida, B., Santos, M., & Justi, R. (2023). Aspects and Abilities of Science Literacy in the Context of Nature of Science Teaching. Science and Education, 32(3), 567–587. https://doi.org/10.1007/s11191-022-00324-4
5. Alshamrani, S. M. (2008). Context, Accuracy, and Level of Inclusion of NAture of Science Concepts in Current High School Physics Textbooks. In A dissertation in partial fulfillment of the requirements for the degee of Doctor of Philosopy in Curriculum & Instruction. http://dx.doi.org/10.1016/j.jaci.2012.05.050
6. Amador-Rodríguez, R., Adúriz-Bravo, A., Valencia-Cobo, J. A., Reinoso-Tapia, R., & Delgado-Iglesias, J. (2021). Prospective primary teachers' views on the nature of science. Journal of Technology and Science Education, 11(2), 403–418. https://doi.org/10.3926/JOTSE.1271
7. Anane, N. M., & Lomotey, V. A. (2023). Perceptions of the Impact Of Availability and Utilisation of Laboratory Facilities On Science Teacher-Trainees' Knowledge and Attitudes Toward Improvisation In Science. Advanced Journal of STEM Education, 1(1), 51–60. https://doi.org/10.31098/AJOSED.V1I1.1568
8. Atakan, M., & Akçay, B. (2022). Representation of Changes about Nature of Science in Turkish Middle School Science Textbooks. Science & Education 2022 33:3, 33(3), 551–580. https://doi.org/10.1007/S11191-022-00403-6
9. Cahyana, C. (2025). Understanding the Nature of Science for Elementary School Students in Rural, Suburban, and Urban Areas. Advanced Journal of STEM Education, 3(1), 1–12. https://doi.org/10.31098/ajosed.v3i1.2990
10. Chaiyabang, M. K., & Thathong, K. (2014). Enhancing Thai Teacher's Understanding and Instruction of the Nature of Science. Procedia - Social and Behavioral Sciences, 116, 563–569. https://doi.org/10.1016/j.sbspro.2014.01.258
11. Dogan, N., & Abd-El-Khalick, F. (2008). Turkish grade 10 students' and science teachers' conceptions of nature of science: A national study. Journal of Research in Science Teaching, 45(10), 1083–1112. https://doi.org/10.1002/tea.20243
12. Go, A. N., & Quicho, R. F. (2023). Perceived Teachers' Teaching Styles and Motivated Strategies for Learning of Year 1 and Year 2 Students in Cita Hati Christian Senior High School, Surabaya Indonesia. International Journal of Research and Innovation in Social Science (IJRISS), VII(2454), 1175–1189. https://doi.org/10.47772/IJRISS
13. Hacieminoglu, E. (2014). In-service Teachers' Perceptions Regarding their Practices Related to Integrating Nature of Science: Case Study. Procedia - Social and Behavioral Sciences, 116, 1268–1273. https://doi.org/10.1016/J.SBSPRO.2014.01.381
14. Hamzah, A. M. (2023). Trends in International Mathematics and Science Study (TIMSS) as A Measurement for Student Mathematics Assessment Development. 12 Waiheru, 9(2), 189–196. https://doi.org/10.47655/12waiheru.v9i2.144
15. Hardianty, N. (2015). Nature of Science : Bagian Penting Dari Literasi Sains. Prosiding Simposium Nasional Inovasi Dan Pembelajaran Sains 2015 (SNIPS 2015), 2015(Snips), 441–444.
16. Hayati Rahayu, A., Sebelas April Sumedang, S., Angkrek Situ No, J., Ari Widodo Pendidikan Biologi, S., & Pendidikan Matematika dan Ilmu Pengetahuan Alam, F. (2019). Understanding of Nature of Science Pre-Service Students and Elementary School Teachers in the Digital Age. Formatif: Jurnal Ilmiah Pendidikan MIPA, 9(2), 161–172. https://doi.org/10.30998/FORMATIF.V9I2.3251
17. Hisanah, N., Koeshandayanto, S., & Sulur, S. (2025). Eksplorasi Literasi Sains Berdasarkan Perbedaan Gender pada Materi Besaran dan Pengukuran Kelas X SMA. JIIP - Jurnal Ilmiah Ilmu Pendidikan, 8(1), 760–770. https://doi.org/10.54371/jiip.v8i1.6572
18. Jiang, F., & McComas, W. F. (2014). Analysis of Nature of Science Included in Recent Popular Writing Using Text Mining Techniques. Science and Education, 23(9), 1785–1809. https://doi.org/10.1007/S11191-014-9703-0
19. Jufri, A. W., Nirmala, S. A., Munib, M., & Dewi, E. S. (2025). Pengetahuan Hakikat Sains (Nature of Sains - NoS) Siswa SMP Negeri dan SMP Islam: Tinjauan Berdasarkan Gender. Bioscientist : Jurnal Ilmiah Biologi, 13(1), 30. https://doi.org/10.33394/bioscientist.v13i1.14530
20. Jumanto, J., & Widodo, A. (2018). Pemahaman Hakikat Sains oleh Siswa Dan Guru SD di Kota Surakarta. Jurnal Komunikasi Pendidikan, 2(1), 20–31. https://doi.org/10.32585/JKP.V2I1.61

21. Kapsala, N., Galani, A., & Mavrikaki, E. (2022). Nature of Science in Greek Secondary School Biology Textbooks. Center for Educational Policy Studies Journal, 12(2). https://doi.org/10.26529/cepsj.1309
22. Khishfe, R. (2017). Consistency of nature of science views across scientific and socio-scientific contexts. International Journal of Science Education, 39(4), 403–432. https://doi.org/10.1080/09500693.2017.1287976
23. Kinskey, M. (2023). The Importance of Teaching Nature of Science: Exploring Preservice Teachers' Views and Instructional Practice. Journal of Science Teacher Education, 34(3), 307–327. https://doi.org/10.1080/1046560X.2022.2100730;JOURNAL:JOURNAL:USTE20;WGROUP:STRING:PUBLICATION
24. Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of Nature of Science Questionnaire: Toward Valid and Meaningful Assessment of Learners' Conceptions of Nature of Science. Journal of Research in Science Teaching, 39(6), 497–521. https://doi.org/10.1002/TEA.10034;REQUESTEDJOURNAL:JOURNAL:10982736;PAGE:STRING:ARTICLE/CHAPTER
25. Lorsbach, A. W., Meyer, A. A., & Arias, A. M. (2019). The Correspondence of Charles Darwin as a Tool for Reflecting on Nature of Science. Science & Education 2019 28:9, 28(9), 1085–1103. https://doi.org/10.1007/S11191-019-00080-Y
26. McComas, W. F. (2015). The Nature of Science & the Next Generation of Biology Education. The American Biology Teacher, 77(7), 485–491. https://doi.org/10.1525/ABT.2015.77.7.2
27. Nugraheny, D. C., & Widodo, A. (2021). Jurnal Visipena Pengaruh Penerapan Model Pembelajaran. Jurnal Visipena, 12(1), 111–123.
28. Savira, D. L., & Bahij, A. Al. (2025). The Effect of Augmented Reality-Based Learning Media on Collaboration and Critical Thinking Skills of Fifth Grade Students in Human Circulatory System Topic at SD Muhammadiyah 12 Pamulang. International Journal of Research and Innovation in Social Science, 9(3s), 5412–5418. https://ideas.repec.org/a/bcp/journl/v9y2025i3sp5412-5418.html
29. Setya Novanto, Y., Djudin, T., Yani, A., Basith, A., & Murdani, E. (2021). Kemampuan Pemahaman Konsep Ipa Pada Siswa SekolahDasar Berdasarkan Gender. Jurnal Pendidikan Dasar Indonesia, 43–46.
30. Siswati, B. H., Susilo, H., & Mahanal, S. (2016). Pengaruh Gender terhadap Keterampilan Metakognitif dan Pemahaman Konsep Peserta Didik IPA dan Biologi di Malang. In Pros. Semnas Pend. IPA Pascasarjana UM (Vol. 1, pp. 748–755).
31. Suratmi, & Widodo, A. (2021). Penerapan Model Pembelajaran NoS Untuk Meningkatkan Pemahaman NoS Siswa Sekolah Dasar. Jurnal Cakrawala Pendas, 7(2), 215–223.
32. Temel, S., Şen, Ş., & Özcan, Ö. (2018). The development of the nature of science view scale (NOSvs) at university level. Research in Science and Technological Education, 36(1), 55–68. https://doi.org/10.1080/02635143.2017.1338251
33. Tursinawati, T., & Widodo, A. (2019). Pemahaman Nature of Science (NoS) Di Era Digital: Perspektif Dari Mahasiswa PGSD. Jurnal IPA & Pembelajaran IPA, 3(1), 1–9. https://doi.org/10.24815/jipi.v3i1.13294
34. Utami, C., & Anitra, R. (2020). Jurnal Kependidikan : Kemampuan Pemahaman Konsep Siswa Berdasarkan Gender pada Pembelajaran Realistic Mathematics Education Berbantuan Alat Peraga PANDU Program Studi Pendidikan Guru Sekolah Dasar , Departemen PGSD , STKIP Singkawang Corresponding Author. 6(3), 475–489.
35. Widodo, A. (2021). Pembelajaran Ilmu Pengetahuan Alam: Dasar-Dasar Untuk Praktik. UPI Press.
36. Widodo, A., Jumanto, J., Adi, Y. K., & Imran, M. E. (2019). Pemahaman Hakikat Sains (NOS) oleh Siswa dan Guru Sekolah Dasar. Jurnal Inovasi Pendidikan IPA, 5(2), 237–247. https://doi.org/10.21831/jipi.v5i2.27294
37. William F. McComas. (2017). Understanding how science works: the nature of science as the foundation for science teaching and learning. School Science Review, 98(365), 71–76.
38. Yanuar, Y., & Widodo, A. (2020). Pengaruh Desain Pembelajaran Berbasis Nature of Science terhadap Pemahaman Siswa Sekolah Dasar. Jurnal Inspirasi Pendidikan, 11(1), 10–18. http://dx.doi.org/