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Representation of the Nature of Science in High School Physics Textbooks in Indonesia

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Abstract

Understanding the Nature of Science (NoS) is widely acknowledged as a fundamental component of scientific literacy and an essential goal in physics education. Textbooks play a pivotal role in shaping students' and teachers' conceptions of science, particularly in educational contexts such as Indonesia, where they serve as the primary instructional resources. This study aimed to analyze how the ten aspects of NoS: empirical, inferential, creative, theory-driven, tentative, scientific method, scientific theories, scientific laws, the social dimension of science, and the social-cultural embeddedness of science are represented and presented in Indonesian high school physics textbooks. Using a descriptive content-analysis approach, five widely used 12th-grade textbooks were examined across five comparable topics: electromagnetic induction, alternating current, electromagnetic radiation, special relativity, and quantum phenomena. Each textbook was analyzed using the Abd-El-Khalick framework and scored on a −3 to +3 rubric to assess the explicitness and informedness of NoS representation. The findings revealed that none of the textbooks entirely covered all ten NoS aspects; the social dimension of science was most frequently represented, while the creative, inferential, and tentative aspects were largely absent. The findings highlight the need for textbook authors and curriculum developers to integrate NoS aspects more explicitly to strengthen students' understanding of scientific processes and reasoning. The results provide practical guidance for improving NoS representation in Indonesian physics textbooks and supporting the development of scientific literacy.

Keywords: nature of science, content analysis, physics textbook, scientific literacy

INTRODUCTION

Scientific literacy has long been recognized as a central goal of science education (Anderson, 2013; Heering, 2015). It encompasses the ability to understand scientific concepts and processes, to make informed decisions, and to participate in community and cultural activities that rely on science and technology (Dani, 2009). For students, mastery of scientific literacy brings significant benefits not only for academic achievement but also for everyday life. Scientific literacy helps them understand contemporary issues such as environmental problems, health, and the economy areas that are increasingly dependent on technological and scientific advancement (Widodo et al., 2019).

One of the fundamental elements that fosters students' scientific literacy is the Nature of Science (NoS) (Ergül et al., 2011; Hodson, 2009; Holbrook et al., 2009). NoS refers to the dimensions that explain how reliable scientific knowledge is constructed and justified (Allchin, 2011). It involves understanding what science is, how science works, and how scientific knowledge interacts with society (Clough & Olson, 2008; McComas et al., 2020). A sound understanding of NoS supports students in developing scientific knowledge (Li et al., 2018) and in building positive attitudes toward science (Ireland et al., 2014). Abd-El-Khalick et al. (2008) identified ten key components that should be integrated into science education: (1) empirical, (2) inferential, (3) creative, (4) theory-driven, (5) tentative, (6) scientific method, (7) scientific theories, (8) scientific laws, (9) social dimensions of science, and (10) social and cultural embeddedness of science.

Integrating NoS aspects into science learning has been widely recognized for its pedagogical benefits (Allchin, 2017; Irzik, 2013). The inclusion of NoS not only enhances students' understanding of scientific content but also improves their ability to interact socially and apply science in real-life contexts (Utami et al., 2022). In physics education, elaborating NoS is considered crucial (Bancong & Song, 2020; Karampelas, 2018; Upahi et al., 2020; Zhang et al., 2022) because it helps students comprehend how scientific knowledge about the physical world is generated. A well-informed perspective on NoS allows learners to appreciate both the strengths and limitations of scientific inquiry (Abd-El-Khalick et al., 2008; Ayık & Coştu, 2020).

To cultivate students' understanding of NoS, it is important that NoS aspects are addressed not only during classroom instruction but also represented in the textbooks that guide teaching and learning (Amaliyah & Erman, 2022). In Indonesia, textbooks are the most commonly used learning resources because most teachers rely on them for planning lessons and selecting teaching strategies (Bancong & Song, 2018; Alajmi, 2012). However, the lack of integration of NoS aspects in textbooks and curricula has been identified as a significant cause of students' limited understanding of NoS (Izci, 2017).

Globally, research has shown that the representation of NoS in science textbooks remains incomplete and uneven. In Turkey, Aydin and Tortumlu (2015) found that the number of NoS aspects decreased as the grade level increased, with the creative aspect being the least represented. Similar patterns were reported in the United States, Nigeria, China, and South Korea, where textbooks often provided unbalanced or partial representations of NoS (Brunner & Abd-El-Khalick, 2020; Park et al., 2019; Upahi et al., 2020; Zhuang et al., 2021; Athifah & Syafriani, 2018).

In the Indonesian context, however, studies on NoS have mostly focused on its classroom implementation and effectiveness rather than its portrayal in learning materials (Nugraheny & Widodo, 2021; Sutinah & Widodo, 2020; Widodo et al., 2019; Widowati et al., 2018; Ardwiyanti et al., 2021; Jannah, Suyana, & Novia, 2019). Research specifically examining the representation of NoS in physics textbooks remains scarce. Therefore, it is necessary to explore the extent to which and how NoS aspects are represented in Indonesian physics textbooks. The findings of this study are expected to advance NoS research within the Indonesian educational context and provide practical insights for teachers, textbook authors, and publishers on how to develop physics textbooks that more effectively represent NoS aspects to enhance students' scientific literacy.

METHODS

This study employed a descriptive content analysis design to identify and describe how the aspects of the Nature of Science (NoS) are represented in Indonesian high school physics textbooks. The analysis focused on both the presence and manner of representation of each NoS aspect, using a theory-driven coding rubric.

Data Sources

The data were drawn from five Indonesian high school physics textbooks developed under the 2013 national curriculum and widely used across schools. The selection of these textbooks was based on a teacher survey administered through Google Forms to identify the most frequently adopted titles in public and private schools. The selected textbooks are listed in TABLE 1.

TABLE 1. Identity of Indonesian physics textbooks used as research samples

Code	Author(s)	Publisher	Year
A	Aris Prasetyo Nugroho., Indasari., & Naila Hilmiyana Syifa	Mediatama	2016
B	Hari Subagya	Bumi Aksara	2018
C	Sunardi., Paramitha., andreas B., & Darmawan	Yrama Widya	2016
D	Bambang Ruwanto	Yudhi Tirta	2017
E	Marthen Kanginan	Erlangga	2018

Sampling Criteria

To ensure comparability, five similar chapters were selected from each textbook: *electromagnetic induction, alternating current, electromagnetic radiation, theory of special relativity,* and *quantum phenomena*. These chapters were chosen based on three considerations:

1. These topics are commonly included in physics textbooks at the Grade XII level.
2. They represent modern physics concepts that require a high level of conceptual reasoning, making them well suited for identifying Nature of Science (NoS) aspects, particularly inferential, creative, and theoretical dimensions.
3. Moreover, these topics provide rich narrative and problem-solving contexts that enable the analysis of both explicit and implicit representations of NoS.

Analytical Framework

The study adopted the NoS framework developed by Abd-El-Khalick et al. (2008, 2017), which includes ten aspects: empirical, inferential, creative, theory-driven, tentative, scientific method, scientific theories, scientific laws, social dimension of science, and social and cultural embeddedness of science. Each aspect in TABLE 2 was examined in terms of its occurrence (frequency of appearance) and form of representation (implicit or explicit).

TABLE 2. The aspects and dimension of NoS

NoS Aspects	Dimension
Empirical	Scientific claims are derived from, and/or consistent with, observations of natural phenomena.
Inferential	Scientific constructs involved can only be accessed through their manifestation or effects.
Creative	Involving creativity to produce scientific knowledge such as when formulating explanations and theoretical entities.
Theory-driven	The influence of scientists' beliefs, perspectives, and theories on the process of observation
Tentative	The possibility of changes in scientific knowledge if new evidence is found.
Scientific method	There is no patented sequential procedure in scientific practices. Scientists observe, compare, measure, speculate, hypothesize, debate, and propose ideas and construct scientific theories.
Scientific theories	Scientific theories are systematic explanations that are based on premises and can promote the existence of non-observable entities.
Scientific laws	Descriptive statements that rule the connections among phenomena

NoS Aspects	Dimension
Social dimension of science	Scientific knowledge is established along with communication and criticism
Social and cultural embeddedness of science	Socio-cultural elements such as religion, politics, and economics, have an impact on the development of science and vice versa

A scoring rubric with a scale from –3 to +3 was employed to evaluate the clarity and consistency with which each aspect was represented. Higher scores correspond to a more explicit and informed portrayal of the nature of science (NoS) aspect. Representative coded statements were recorded to demonstrate how each aspect was manifested in the textbooks.

Reliability Procedures

To strengthen the trustworthiness of the findings, inter-rater reliability was established through a multi-stage validation process. Two experts in physics education independently coded the same sample of textbook sections. Their coding results were compared and discussed to resolve discrepancies. Inter-rater reliability was computed as 90%, which is considered acceptable for qualitative content analysis (Miles et al., 2014). The detailed coding manual and example segments were reviewed to ensure scoring consistency. In addition, member checking was conducted by presenting the coding results to the same experts for confirmation and refinement. Data triangulation across textbooks further enhanced credibility.

Data Analysis

The results were presented in tables and figures to illustrate both the distribution and the quality of NoS representation across textbooks. The data analysis involved two main steps:
1. Quantitative counting of the frequency of each NoS aspect in the five textbooks.
2. Qualitative interpretation of how these aspects were represented explicitly or implicitly based on the scoring rubric.

RESULTS AND DISCUSSION

This section presents two interrelated outcomes of the analysis: (1) the extent to which the ten aspects of the Nature of Science (NoS) are covered across five widely used Indonesian Grade XII physics textbooks (Books A–E), and (2) the manner in which these aspects are presented, as measured by their degree of explicitness and informedness using a −3 to +3 scoring rubric. Taken together, these outcomes provide a comprehensive account of not only the distribution and frequency of NoS aspects within the textbooks, but also the quality of their epistemic representation as conveyed to readers. The results reported in this section begin with an examination of the proportional occurrence of each NoS aspect in the analyzed textbooks, thereby offering an overview of patterns of emphasis and omission across the instructional materials.

Coverage of NoS aspects across textbooks. TABLE 3 summarizes the frequency with which each NoS aspect was identified in the sampled chapters of Books A–E. In aggregate, 208 coded instances were detected. The social dimension of science was the most frequently represented aspect (20.7%), followed by scientific method (16.8%) and the social and cultural embeddedness of science (16.3%). Mid-range coverage was observed for scientific laws (13.9%) and scientific theories (13.0%). Lower frequencies were recorded for empirical (9.1%) and theory-driven (7.7%) aspects, while tentative (1.4%) and inferential (1.0%) were rare. Notably, the creative aspect did not appear in any book (0%). These distributions portray a pattern in which socially oriented and procedure-oriented ideas are emphasized, whereas epistemic features central to model building, inference, and the revisability of knowledge are substantially underrepresented.

TABLE 3. Frequency of NoS aspect occurrence across five physics textbooks

NoS Aspects	Frequency					Total	Percentage (%)
	A	B	C	D	E		
Empirical	5	3	4	4	3	19	9.1
Inferential	0	0	0	2	0	2	1.0
Creative	0	0	0	0	0	0	0
Theory-driven	3	4	2	4	3	16	7.7
Tentative	3	0	0	0	0	3	1.4
Scientific Method	11	7	4	5	8	35	16.8
Scientific theories	6	5	6	4	6	27	13.0
Scientific laws	5	4	8	5	7	29	13.9
Social dimension of science	5	7	10	11	10	43	20.7
Social and cultural embeddedness of science	10	5	3	7	9	34	16.3
Total	**48**	**35**	**37**	**42**	**46**	**208**	

At the level of individual books, none represented all ten aspects. Books A and D each covered eight aspects; Books B, C, and E each covered seven aspects. The absent aspects were largely consistent across books: creative was universally missing; inferential appeared only in Book D; and tentative appeared only in Book A. Within-book emphases also varied: Book A concentrated on scientific method and social–cultural embeddedness; Book B emphasized scientific method and the social dimension of science; Book C weighted social dimension, scientific laws, and scientific theories; Book D prioritized the two social facets; and Book E favored the social facets alongside scientific method, laws, and theories. This heterogeneity indicates that students' exposure to NoS ideas depends strongly on the textbook and chapter chosen, with systematic gaps across several core aspects.

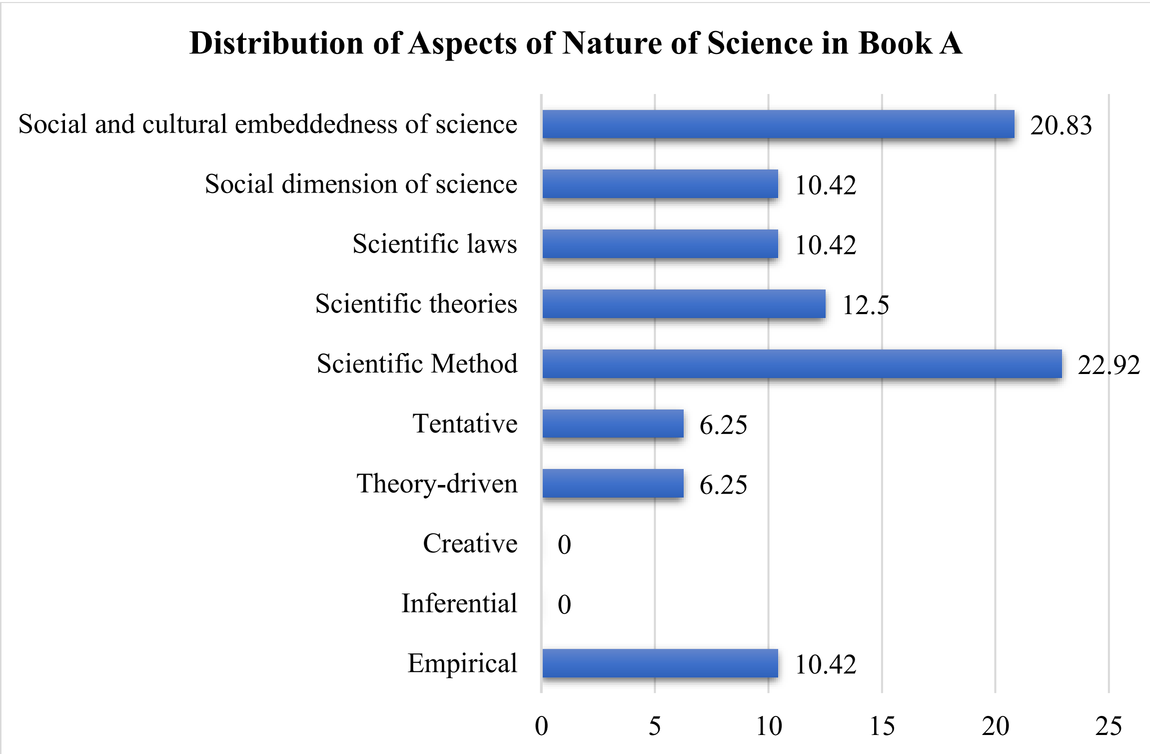

FIGURE 1. Distribution of Aspects of Nature of Science in Book A

As seen in FIGURE 1, on book A, there are eight aspects of NoS detected, and scientific method and sosial and cultural embeddedness of science aspects occupy the biggest proportion of occurrence, just over one-fifth of the entire NoS aspects presented. Scientific theories ranked third, followed by empirical aspect. Furthermore, social dimension of science and scientific laws has the proportion of 10.42% each, while tentative and theory-driven also emerge in the same frequency that is 6.25%. Meanwhile, creative and inferential aspects did not addressed at all in this book A.

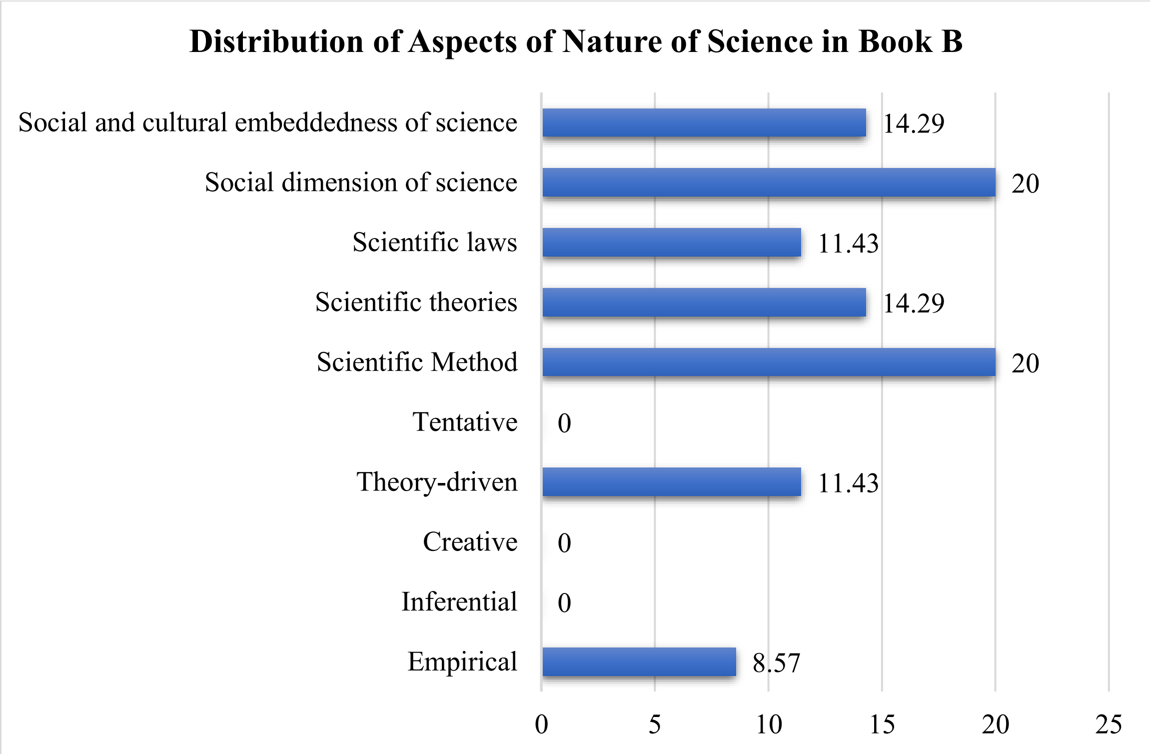

FIGURE 2. Distribution of Aspects of Nature of Science in Book B

Based on the distribution shown in FIGURE 2, Book B demonstrates an uneven representation of the Nature of Science (NoS) aspects. The social dimension of science and the scientific method are the most prominently represented aspects, each accounting for 20% of the total occurrences, indicating a strong emphasis on science as a socially situated activity and on procedural understandings of scientific inquiry. These are followed by the social and cultural embeddedness of science and scientific theories, both represented at 14.29%, suggesting moderate attention to the broader contextual and theoretical foundations of scientific knowledge. Scientific laws and theory-driven aspects appear less frequently, each comprising 11.43%, while the empirical aspect is minimally represented at 8.57%. Notably, the creative, inferential, and tentative aspects are entirely absent from Book B. This pattern suggests that although the textbook highlights social and methodological elements of science, it provides limited opportunities for students to engage with key epistemic dimensions related to creativity, inference, and the tentative nature of scientific knowledge, which are essential for developing a comprehensive understanding of the Nature of Science.

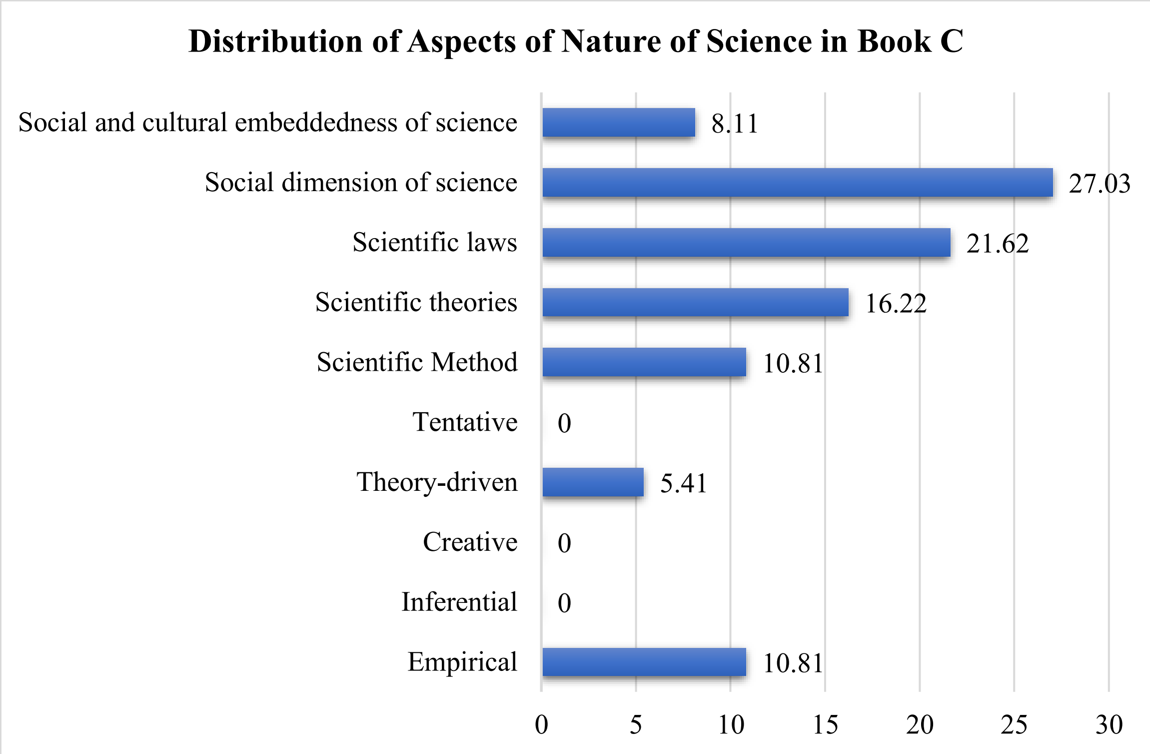

FIGURE 3. Distribution of Aspects of Nature of Science in Book C

The distribution of the Nature of Science (NoS) aspects in Book C indicates a clear dominance of the social dimension of science, scientific laws, and scientific theories (FIGURE 3). Among these, the social dimension of science emerges as the most frequently represented aspect, accounting for 27.03% of the total NoS occurrences, followed by scientific laws at 21.62% and scientific theories at 16.22%. This pattern suggests a strong emphasis on science as a socially mediated enterprise and on established bodies of scientific knowledge. The scientific method and empirical aspects are moderately represented, each comprising 10.81%, indicating that procedural and evidence-based elements of science receive some attention, albeit to a lesser extent. In contrast, the theory-driven aspect is minimally represented, with a proportion of only 5.41%, reflecting limited discussion of how theoretical frameworks guide scientific inquiry and interpretation. Notably, and consistent with the pattern observed in Book B, the inferential, creative, and tentative aspects are entirely absent from Book C. This uneven representation suggests that while the textbook highlights social and structural dimensions of scientific knowledge, it provides limited exposure to key epistemic processes underlying scientific reasoning, thereby constraining students' opportunities to develop a comprehensive understanding of the Nature of Science.

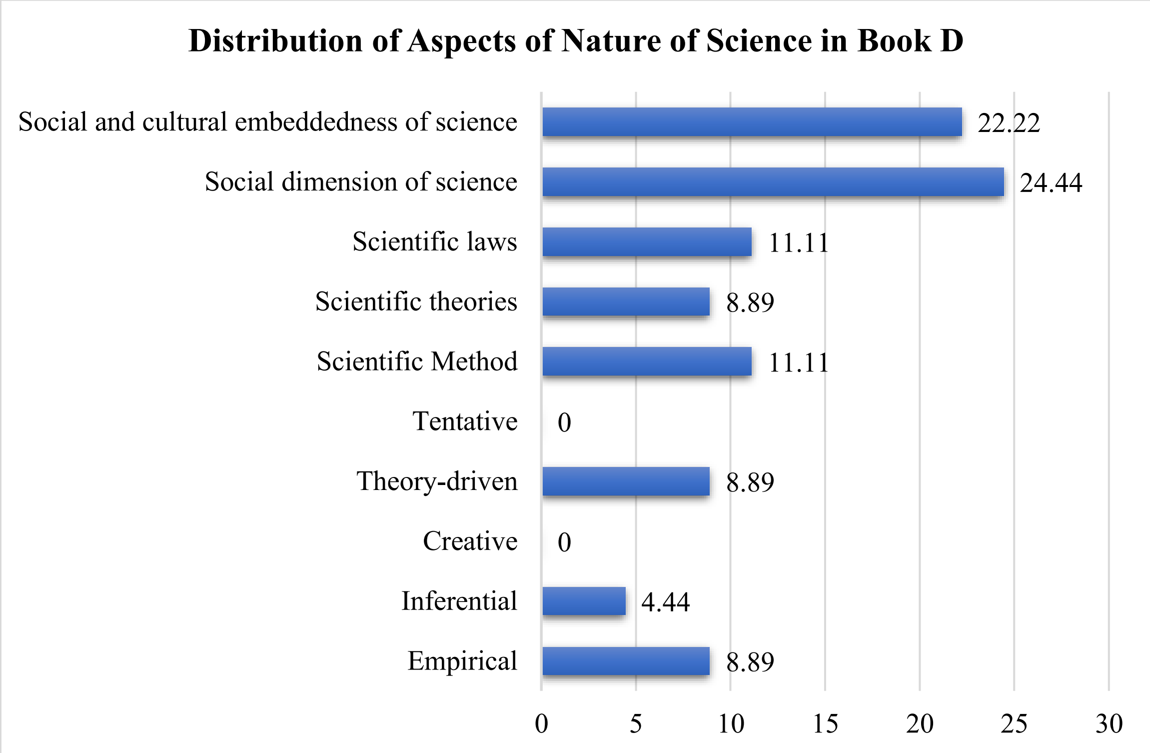

FIGURE 4. Distribution of Aspects of Nature of Science in Book D

The analysis of Book D (FIGURE 4) reveals a strong emphasis on socially oriented aspects of the Nature of Science (NoS). The social dimension of science constitutes the largest proportion at 24.44%, followed closely by the social and cultural embeddedness of science at 22.22%, indicating that this textbook places considerable focus on the societal and cultural contexts in which scientific knowledge is developed. The scientific method and scientific laws are represented in equal proportions, each accounting for 11.11% of the total NoS occurrences, suggesting a balanced treatment of procedural and structural components of science. In addition, the empirical, scientific theories, and theory-driven aspects are represented at comparable levels, each comprising 8.89%, reflecting a relatively even but modest emphasis on evidence-based reasoning and theoretical frameworks. By contrast, the inferential aspect appears infrequently, with a proportion of only 4.44%, indicating limited attention to reasoning processes that link data to scientific claims. Furthermore, the creative and tentative aspects are entirely absent from Book D. Overall, despite the dominance of social-related NoS aspects, the remaining represented aspects are distributed in a relatively balanced manner, with most appearing at proportions close to or above 10%, highlighting both the strengths and gaps in the textbook's portrayal of the Nature of Science.

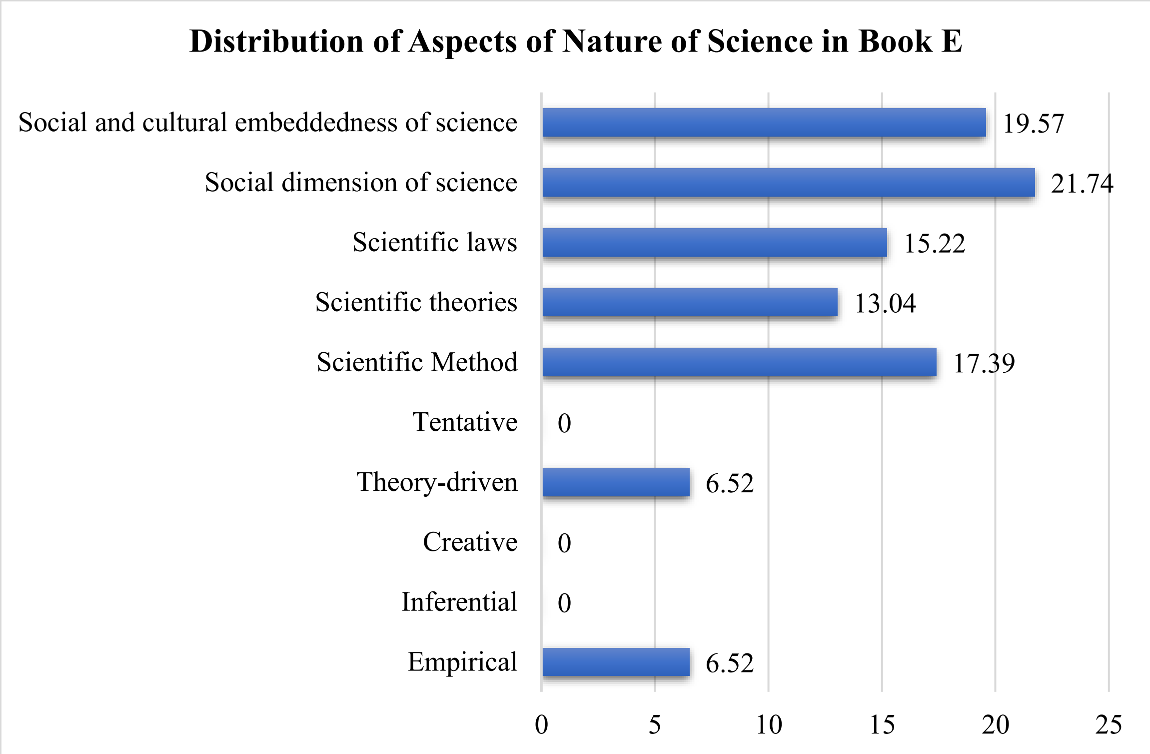

FIGURE 5. Distribution of Aspects of Nature of Science in Book E

The distribution of the Nature of Science (NoS) aspects in Book E (FIGURE 5) shows a predominance of social-related dimensions, with the social dimension of science emerging as the most frequently represented aspect at 21.74%, followed closely by the social and cultural embeddedness of science at 19.57%. This indicates a strong emphasis on the societal and cultural contexts of scientific knowledge. The scientific method is also prominently featured, accounting for 17.39% of the total NoS occurrences, suggesting considerable attention to procedural aspects of scientific inquiry. Scientific laws and scientific theories are moderately represented, with proportions of 15.22% and 13.04%, respectively, reflecting a balanced presentation of established scientific knowledge. In contrast, the theory-driven and empirical aspects appear infrequently, each comprising only 6.52%, indicating limited emphasis on the role of theoretical frameworks and empirical evidence in guiding scientific explanations. Notably, the inferential, creative, and tentative aspects are entirely absent from Book E. Overall, while Book E demonstrates a relatively broad distribution of several NoS aspects, the lack of representation of key epistemic dimensions related to inference, creativity, and the tentative nature of scientific knowledge suggests an incomplete portrayal of the Nature of Science.

To analyze how NoS aspects are represented in the textbooks, a score is assigned using the rubric developed by Abd-El-Khalick et al. (2008). Based on the data analysis, most NoS aspects appeared more than once across all textbooks. The number of quotes found is then noted, analyzed, and scored to see whether the NoS aspects are represented implicitly or explicitly. Each item's score ranges from -3 to +3; the more positive the score, the more explicit, informed, and consistent the NoS aspect is. In this study, more than one item is assessed in each aspect; thus, the scores (in TABLE 4) are the accumulations of all items in each NoS aspect presented (see TABLE 3). For instance, in Book A, there were 48 quotes. If all quotes are delivered in an explicit and informed way, the maximum score can reach 144 points, and this applies to the other book as well. The scores in TABLE 4 were the final scores after assessing each quote in each aspect of NoS.

TABLE 4 The Cumulative scores of all NoS aspects and book-level maxima

	A	B	C	D	E
Total score	56	39	42	40	54
Max. score	144	105	111	126	138

TABLE 4 depicts the cumulative scores of all items recognized as NoS aspects in each textbook. The analysis process was done by comparing the total score obtained from the assessment of all items that appeared. The results of the analysis suggest that the score for each textbook is still far from the maximum, indicating that most of the NoS aspects in those five books are represented implicitly.

For interpretability, TABLE 5 reports normalized scores. These ratios ranged from Book D (0.317) to Book E (0.391), with Books A–C clustered between 0.371 and 0.389. Thus, even where NoS aspects appeared relatively often (e.g., the social facets), they were typically not elaborated with explicit definitions, reflective questioning, or historical/epistemic framing that would help students generalize beyond the immediate context. Conversely, aspects with very low frequencies (e.g., inferential, tentative, creative) necessarily offer few opportunities for explicit treatment.

TABLE 5. Normalized explicitness scores

Book	Score	Interpretation
A	0.389	Mostly implicit presentation
B	0.371	Mostly implicit presentation
C	0.378	Mostly implicit presentation
D	0.317	Predominantly implicit presentation
E	0.391	Mostly implicit presentation

Synthesis of coverage and presentation. Integrating the two lenses clarifies the instructional signal available to textbook users. First, the breadth of coverage is limited: across five books and five modern/core physics topics, the creative aspect is absent, inferential appears only in one book, and tentative appears only in another. Second, depth of treatment is modest: normalized explicitness scores cluster around 0.32–0.39, suggesting that, on average, instances of NoS are presented implicitly (e.g., embedded in procedural descriptions or narratives) rather than explicitly (e.g., defined, problematized, or connected to broader epistemic principles). The combined effect is that students relying on these texts are far more likely to encounter NoS as a diffuse background to content rather than as a deliberately taught component of scientific literacy.

The present analysis reveals a consistent pattern of partial and predominantly implicit representations of the Nature of Science (NoS) across five widely used Indonesian grade-XII physics textbooks, with the social dimension of science as the most frequently represented aspect (20.7%), followed by scientific method (16.8%) and the social–cultural embeddedness of science (16.3%). In contrast, creative did not appear at all, and inferential (1.0%) and tentative (1.4%) were rare in Table 3. When viewed through the lens of presentation quality, normalized explicitness scores ranged from 0.317 to 0.391 (TABLE 5), indicating that most instances were treated implicitly or in only partially informed ways, even in books that referenced NoS relatively often (TABLE 4). These findings matter because the form of representation is pivotal for learning: evidence shows that implicit treatments e.g., leaving epistemic ideas to be “picked up” from activities or narratives, do not reliably yield robust NoS understandings, whereas explicit-reflective approaches do (Abd-El-Khalick & Lederman, 2000; Khishfe & Abd-El-Khalick, 2002; McComas, Clough, & Nouri, 2020). Thus, the data suggest that students who rely on these textbooks are more likely to encounter NoS as a diffuse background context rather than as a component to be learned deliberately and reflectively.

International textbook studies provide a useful comparative frame. Analyses across the United States, China, Turkey, South Korea, and Nigeria have repeatedly documented incomplete and imbalanced coverage of NoS, alongside a tendency toward implicit treatments (Abd-El-Khalick et al., 2008, 2017; Wei et al., 2013; Izci, 2017 ; Park, Yang, & Song, 2019; Upahi, Ramnarain, & Ishola, 2020; Zhuang et al., 2021; Brunner & Abd El Khalick, 2020). Our results align with this global picture but extend it in two ways germane to Indonesia: first, by mapping NoS across multiple modern and core physics topics that are particularly fertile for epistemic discussion (electromagnetic induction, alternating current, electromagnetic radiation, special relativity, and quantum phenomena); and second, by quantifying explicitness with a comparable index, which clarifies that low explicitness is a systematic property of the corpus rather than an artifact of chapter length or frequency of coded segments. The convergence between our findings and the international literature underscores both the persistence of the problem and the opportunity to use established remedies drawn from prior work.

The distribution we observed socially oriented aspects and a generalized view of "method" being emphasized while creative, inferential, and tentative are marginalized has recognizable roots in textbook craft and curriculum signals. Scholars have long noted that textbooks tend to stabilize scientific knowledge, presenting laws and theories in polished form and framing method as an algorithmic sequence, thereby downplaying the nonlinear, creative, and theory laden nature of inquiry and the revisability of claims (Allchin, 2011; Abd-El-Khalick et al., 2008, 2017). Socially embedded content (e.g., brief vignettes, applications, or societal implications) is comparatively easier to add without reworking explanations or problem sets, which may explain the higher frequencies of the social facets we report. However, when tentativeness and inferential reasoning are not made explicit, students may not appreciate how evidence underdetermines theory, how models extend beyond direct observables, or why scientific claims can legitimately change with new data key epistemic ideas central to scientific literacy (Allchin, 2017; Irzik, 2013; McComas et al., 2020). The absence of creative also deprives learners of seeing how imagination, model building, and theory articulation operate as legitimate scientific practices, not embellishments.

From an instructional standpoint, the shift advocated by prior research is unambiguous: explicit reflective treatments must be embedded across topics and chapters, with NoS ideas named, problematized, and revisited so that learners can generalize beyond a single case (Abd El Khalick & Lederman, 2000; Khishfe & Abd El Khalick, 2002). In practical textbook terms, this means pairing content expositions with epistemic prompts ("*What counts as evidence here?*" "*How could this model change with new data?*"), historical/contextual episodes that foreground uncertainty, inference, and creativity, and meta commentary that makes theory ladenness explicit (Allchin, 2017; McComas et al., 2020). Our normalized scores (TABLE 5) highlight how rare such elements currently are; moving these ratios upward would require authors and editors to plan for systematic distribution of NoS aspects and to design tasks that ask students to reason about evidence, models, and revisability rather than only to reproduce algorithms or definitions.

Because textbooks operate within editorial and production ecologies, improvement also hinges on processes beyond single authorship. Research on author–editor–publisher interactions shows that institutional templates, market cues, and review heuristics powerfully shape how NoS appears on the page (DiGiuseppe, 2014) . In systems where textbooks still function as the de facto curriculum as is often the case in Indonesia these dynamics are amplified (Bancong & Song, 2018; Amaliyah & Erman, 2022). The implication is that publishers, editorial boards, and ministries should adopt NoS style sheets or checklists aligned with the ten aspect framework (Abd-El-Khalick et al., 2008), explicitly tracking aspect coverage and explicitness across chapters before sign off. Such process level levers complement the well documented impact of textbooks on classroom decisions and student learning (Tarr et al., 2008; Alajmi, 2012), and they could help counter the observed clustering of aspects around social themes and generalized method while neglecting creative, inferential, and tentative dimensions.

For teachers, the present profile both cautions and guides. Classroom studies in Indonesia have shown that when NoS is taught explicitly and reflectively often within inquiry or context rich lessons— students' scientific literacy and NoS conceptions improve (Widodo, Widowati, & Setyaningsih, 2019; Sutinah & Widodo, 2020; Widowati, Widodo, & Anjarsari, 2018). Given the textbooks' limitations, teachers can leverage existing content but layer on explicit questioning, small group critique of explanations, and short reflective writing tied to the tentative and inferential status of claims. This bridging is particularly important in modern physics topics, where evidence model coordination and theory ladenness are salient and can be made visible with carefully chosen examples and prompts (Park, Yang, & Song, 2019; Li et al., 2018; Karampelas, 2018). In other words, until textbook revisions catch up, pedagogical mediation remains a viable path to making NoS learnable from the same pages students already use.

The topic suite sampled here induction, alternating current, electromagnetic radiation, special relativity, and quantum phenomena offers particularly strong affordances for addressing the very aspects that were least represented. The inferential nature of theory construction in quantum and relativity, for example, invites discussions about unobservable entities, modeling trade offs, and the role of indirect evidence, while electromagnetic topics foreground the theory driven lens in coordinating field concepts, equations, and idealizations. Prior work argues that such topics are not merely content rich but epistemically rich, and thus ideal for explicit NoS work if instructional materials make those epistemic moves transparent (Park et al., 2019; Li et al., 2018; Upahi et al., 2020; Karampelas, 2018). Our results suggest that, in their current form, the sampled chapters miss that opportunity. Rectifying this would involve inserting purpose built NoS elements at conceptually strategic points, rather than relegating NoS to prefatory remarks or sidebars detached from problem solving.

Methodologically, employing a ten aspect coding scheme and the −3 to +3 rubric (Abd-El-Khalick et al., 2008, 2017) enabled us to see both what is present and how it is presented. The added normalized explicitness index makes comparisons across books with different densities of NoS references more interpretable and highlights a system level tendency toward implicitness. At the same time, these metrics should be read alongside qualitative exemplars from the texts, because frequency counts can mask the pedagogical salience of a single, well crafted explicit prompt or historical case. Future audits could extend this approach by systematically sampling end of chapter features (e.g., exercises, lab prompts, discussion questions) and by examining visual and symbolic representations, which often carry epistemic messages in physics (e.g., idealizations, diagram conventions).

Several limitations frame interpretation. The sample comprises five grade XII textbooks and five comparable topics; this strengthens within grade comparability but narrows generalization to other grades or disciplines. Coding focused on textual segments that conveyed an identifiable NoS idea; some epistemic meanings might reside in tasks or images not captured as quotes. Inter coder agreement of 90% for aspect identification indicates acceptable consistency, but future work might report additional reliability indices (e.g., Cohen's κ) and examine how editorial cycles or edition updates shift NoS coverage over time (Abd-El-Khalick et al., 2017). A broader, cross grade audit that pairs content analysis with classroom observations could clarify how teachers mediate textbook NoS to students. These boundaries notwithstanding, the present study offers actionable evidence for redesigning Indonesian physics textbooks to align with international best practices for explicit, balanced NoS representation.

CONCLUSION

This study reveals that the representation of the Nature of Science (NoS) in Indonesian Grade XII physics textbooks remains fragmented, uneven, and largely implicit. Although all analyzed textbooks include certain NoS aspects, none comprehensively address the full spectrum of the ten established dimensions, with a clear dominance of the social dimension of science and a notable absence or marginalization of creative, inferential, and tentative aspects. The predominance of implicit rather than explicit NoS representations suggests that textbooks may inadequately support students in developing an informed understanding of how scientific knowledge is constructed, justified, and revised. Given the central role of textbooks in Indonesian physics classrooms, these findings highlight a critical gap between curricular goals related to scientific literacy and the epistemic messages conveyed through instructional materials (Asriadi and Istiyono, 2020). Consequently, there is a pressing need for textbook authors, editors, and curriculum developers to more deliberately and explicitly integrate NoS aspects across physics topics, ensuring that textbooks function not merely as repositories of content knowledge but as effective tools for fostering students' epistemic reasoning and scientific literacy.

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