

Theoretical Developments and Position of Philosophy of Science in the 21st Century: A Systematic Literature Review

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Abstract

This article examines the development and position of the philosophy of science within the dynamics of 21st-century knowledge, characterized by rapid technological advancement, interdisciplinarity, the dominance of big data, and the growing emphasis on applied science. The aim of this study is to assess the critical relevance of the philosophy of science in both global and Indonesian contexts. Using a conceptual approach and a Systematic Literature Review (SLR) of primary and secondary literature from 2020 to 2025, this study finds that the philosophy of science has not been marginalized but has undergone a transformation of its role into embedded critical reflection. Global analysis indicates a shift from the philosophy of science toward philosophy in science, particularly in addressing the complexity of big data, the validity of interdisciplinary knowledge, and the ethical dilemmas of new technologies. Analysis of the Indonesian literature reveals critical awareness regarding reductionism and social relevance, yet also uncovers gaps in the internalization of philosophical perspectives into research policies, curricula, and research ethics governance. These findings imply the need to strengthen the science ecosystem through the integration of the philosophy of science into research policy, higher education curricula, and adaptive ethics forums, in order to support reflective evaluation, foster critical scientists, and strengthen research governance in the 21st century.

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INTRODUCTION

The 21st century is marked by rapid and complex transformations in the landscape of knowledge. The development of the digital revolution, the expansion of big data and analytics, the convergence of technologies (NBIC: Nanotechnology, Biotechnology, Information Technology, and Cognitive Science), and the increasing demand for science-based solutions have fundamentally transformed the practices, institutions, and epistemology of science (Kalganov, 2023; Stilgoe, 2020). In this context, science is no longer understood as a stable theoretical system, but

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rather as a dynamic practice integrated with global technological, economic, and social networks.

These changes have reignited fundamental questions regarding the position and relevance of the philosophy of science. Amid the dominance of data-driven approaches, pressures for research productivity, and a focus on applied innovation, philosophical reflection is often perceived as an abstract activity detached from scientific practice (Baroud et al., 2025; Kassymova et al., 2025). However, recent developments indicate that the philosophy of science is not being marginalized but is undergoing a significant transformation of its role. This shift is evident in the shift in orientation from the “philosophy of science” toward “philosophy in science” and “philosophy of science in practice,” which positions philosophy as an integral part of the knowledge production process (Crasnow, 2025; Smith, 2021).

Globally, developments in contemporary philosophy of science indicate a shift from foundationalist approaches toward a more contextual analysis of scientific practice. This includes a focus on the epistemology of data-intensive science, which challenges the traditional relationship between data, theory, and explanation (Boon et al., 2022; Huggett, 2020), as well as the growing need for epistemic integration in interdisciplinary research (Dalton et al., 2022). Furthermore, the expansion of the scope of the ethics of science from mere research integrity toward the ethics of knowledge underscores the importance of scientific responsibility regarding social, political, and environmental impacts (Munn et al., 2018). Within the digital knowledge ecosystem, epistemic authority is also undergoing a significant shift due to the increasingly widespread distribution of knowledge sources (Nasrudin et al., 2026). This transformation underscores that the philosophy of science retains critical relevance in addressing the complexities of modern science (Okasha, 2022).

Nevertheless, systematic studies linking these global developments to the context of developing nations, particularly Indonesia, remain relatively limited. In the Indonesian context, the philosophy of science is often positioned as a theoretical discipline within the higher education curriculum and has not yet been fully integrated into empirical research practice (Khairanis & Aldi, 2024). On the other hand, national research policy faces pressure to boost scientific productivity and innovation, as reflected in various development policies and performance indicators based on quantitative outputs (Cao, 2020; Purba, 2025). This situation risks creating a disconnect between epistemological reflection and the practice of knowledge production, particularly regarding scientific validity, research integrity, and the social relevance of science (Engkizar et al., 2024; Engkizar et al., 2025; Valverde-Berrocso et al., 2020).

This gap highlights the need for systematic research to bridge global theoretical developments with local contexts. Furthermore, discourse in Indonesia also reveals efforts to contextualize science through concepts such as “down-to-earth science” and “transformative science,” which emphasize social relevance (Fetmawati et al., 2025), as well as debates regarding the relationship between the universalism and particularism of knowledge (Ibad et al., 2025). However, the extent to which this discourse adopts and integrates developments in contemporary philosophy of science has not yet been comprehensively examined.

Based on this, this article employs a systematic literature review approach to comprehensively analyze developments in the philosophy of science within the dynamics of 21st-century knowledge, focusing on global and Indonesian literature

from 2020 to 2025. Through this approach, this article not only synthesizes global theoretical developments but also analyzes the representation of the philosophy of science in Indonesian academic literature and identifies the gap between philosophical discourse and its implementation in research and higher education policies. In line with this analytical framework, this study is formulated into the following research questions:

- RQ1. What are the major theoretical developments in philosophy of science in the context of 21st-century knowledge dynamics?
- RQ2. How is the role of philosophy of science reflected in Indonesian academic discourse (2020–2025)?
- RQ3. What gaps and implications can be identified for integrating philosophy of science into research policy, higher education, and research ethics in Indonesia?

METHODS

This article employs the Systematic Literature Review (SLR) method to analyze and synthesize the development of philosophical discourse on science in Indonesia during the period 2020–2025. The SLR approach was chosen because it enables researchers to collect, filter, and critically examine previous studies in a structured and transparent manner, thereby strengthening the conceptual analysis with empirical grounding (Lame, 2019; Schröer et al., 2021; Snyder, 2019; Winnaandhini & Santosa, 2025). The research process follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework, which consists of four main stages: identification, selection, eligibility, and inclusion of articles (O’Dea et al., 2021; Page et al., 2021).

In the identification stage, articles were collected from reputable databases such as Garuda (Garba Rujukan Digital), Neliti, SINTA (Science and Technology Index), university journal portals (UI, UGM, ITB, UNJ, etc.), and Scopus. Searches were conducted using keywords including “filsafat ilmu,” “epistemologi ilmu,” “filosofi sains,” “etika penelitian,” “integritas akademik,” “kebijakan riset,” “ekosistem riset,” “big data,” and “interdisipliner,” combined with “Indonesia” to ensure contextual relevance. The selection stage involved filtering articles based on inclusion criteria: peer-reviewed journal or conference papers published between January 2020 and March 2025, explicitly addressing theoretical aspects of philosophy of science, epistemology, or research ethics, and authored by Indonesian scholars or focusing on the Indonesian context. Exclusion criteria included non-scientific articles, superficial mentions without substantive analysis, and duplicate publications (Engkizar et al., 2025; Martinez-Mosquera et al., 2020; Tosi et al., 2024).

The eligibility stage required a deeper examination of abstracts, research methods, and relevance to research objectives. Articles meeting these criteria were read in full to extract key findings. Finally, in the inclusion stage, 15 articles were identified as the core corpus for analysis (Busral et al., 2025; Card & Giuliano, 2016; Engkizar et al., 2023). The selected literature was then subjected to thematic analysis, through which recurring themes such as responses to technological development, critiques of positivism, science–society relations, and recommendations for education were identified (Akyuni et al., 2025). These themes were critically compared with global theoretical frameworks to highlight alignments, gaps, and unique contributions of the Indonesian discourse (Kassymova et al., 2025;

Mutiaramses et al., 2025). The synthesis of findings is presented in tabular and narrative form to provide a comprehensive overview of the state of philosophical inquiry into science in Indonesia.

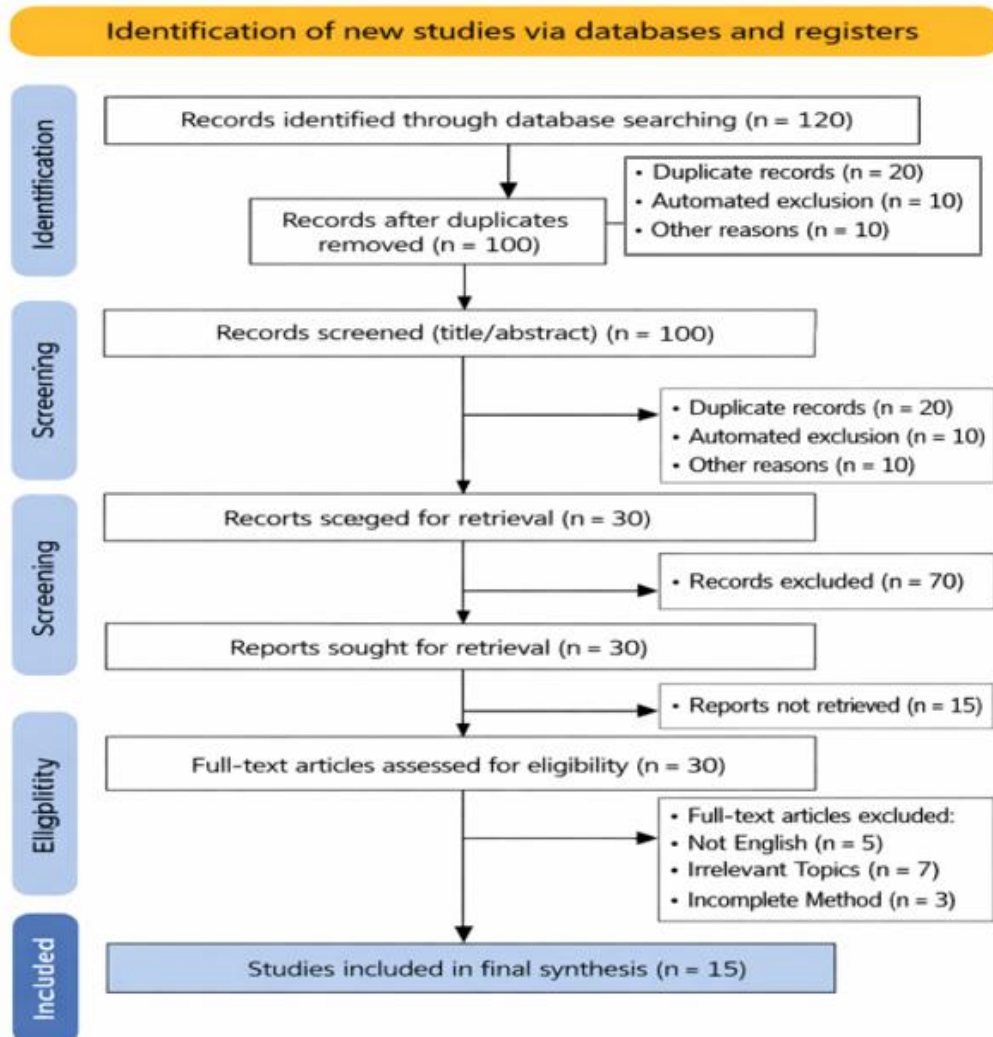


Fig 2. Flowchart of literature selection procedure

RESULT AND DISCUSSION

RQ 1. Major Theoretical Developments in Philosophy of Science

Global analysis reveals a shift in the philosophy of science from an external scrutineer to an embedded critic. In the context of big data, the philosophy of science functions as critical scaffolding, emphasizing that data never “speaks for itself” (Martini, 2016), but is instead laden with epistemic decisions and values (Huggett, 2020). The fundamental question that arises is: what kind of knowledge is generated from big data? Is it merely superficial correlations or deeper causal explanations?

Furthermore, the philosophy of science has evolved into an integrative epistemology that facilitates cross-disciplinary communication through “trading zones” (Stang Våland et al., 2021) and “boundary objects” such as “risk” or “ecosystem” (Dalton et al., 2022). The role of the philosophy of science is no longer that of a referee, but rather a facilitator of coherent and responsible knowledge integration.

RQ 2. The Role of Philosophy of Science in Indonesian Academic Discourse (2020–2025)

A synthesis of the Indonesian literature reveals a positive trend toward critical awareness of contemporary challenges. [Prabowo & Rahmadian \(2022\)](#); [Wahyudi et al \(2024\)](#) highlight the epistemological and ethical implications of big data and AI. [Purba \(2025\)](#) critique research performance measurement systems as a form of scientism. [Fetmawati et al \(2025\)](#); [Ibad et al \(2025\)](#) emphasize social relevance and local epistemology, while [Khairanis & Aldi \(2024\)](#); [Yore \(2018\)](#) expand the role of the philosophy of science into science education and public literacy.

However, a gap persists: the discourse on the philosophy of science remains dominant in the discursive sphere but has not yet been internalized into research policies or core curricula. Discussions tend to be reactive to global trends and have not yet produced an original philosophical framework rooted in the Indonesian context. Fragmentation is also evident as research ethics, science policy, and epistemology operate in isolation ([Asy et al., 2024](#); [Boon et al., 2022](#)).

Table 2. Global vs. Indonesian Themes in the Philosophy of Science (2020–2025)

Thema	Global Literature	Indonesian Literature	Gap Notes
Big Data & Epistemology	(Laksmi et al., 2024 ; Rachmawaty, 2017)	(Fadli et al., 2026 ; Fatimah et al., 2025)	Indonesian studies focus on ethics, with limited discussion on data curation.
Interdisciplinarity & Boundary Objects	(Tondeur et al., 2021 ; West et al., 2020)	(Surya Arfan et al., 2025)	Integration remains conceptual, with no practical models yet developed.
Critique of Scientism	(Campbell & Jamieson, 2024 ; Yan et al., 2020)	(Saputra & Mayurida, 2025)	Strong critique exists, but alternative evaluation instruments have not been produced.
Social Relevance & Transformation	(Smith, 2021)	(Fetmawati et al., 2025 ; Subagiya, 2023)	Social relevance is emphasized, but policy implementation remains minimal.
Knowledge Ethics	(Kalganov, 2023 ; Munn et al., 2018 ; Stilgoe, 2020)	(Salam & Ismail, 2025)	National ethics forums have not yet been established, and ethics committee capacity remains limited.

Table 2 presents a comparison of themes in the philosophy of science in global and Indonesian literature for the period 2020–2025. The analysis indicates that big data and epistemology are among the dominant focuses. Global literature emphasizes the complexity of data curation and modeling, while Indonesian literature highlights ethical and methodological implications ([Huggett, 2020](#); [Martini, 2016](#); [Prabowo & Rahmadian, 2022](#)). This indicates that the Indonesian discourse remains at a normative stage, having not yet developed more technical epistemological frameworks.

Regarding interdisciplinary themes and boundary objects, global literature [Dalton et al \(2022\)](#); [Stang Våland et al \(2021\)](#) has developed the concept of “trading zones” as spaces for cross-disciplinary collaboration. In contrast, the Indonesian literature [Ibad et al \(2025\)](#) remains limited to conceptual discussions regarding epistemic dialogue, lacking practical models of integration. This gap highlights the need for the development of more applied collaborative methodologies in

Indonesia.

The theme of criticism against scientism also emerges strongly. [Munn et al \(2018\)](#); [Okasha \(2022\)](#) highlight the dangers of metric reductionism in research evaluation, while [Purba \(2025\)](#) criticize the research performance measurement system in Indonesia as a form of scientism. However, Indonesian criticism remains at the discursive level and has not yet produced alternative evaluation instruments that can be adopted as policy ([Engkizar et al., 2019](#)).

In terms of social relevance and transformation, the global literature [Nasrudin et al \(2026\)](#); [Smith \(2021\)](#) emphasizes the importance of epistemic integration with socio-political issues, whereas the Indonesian literature highlights the relevance of the philosophy of science to science education and public literacy. Nevertheless, the implementation of policies supporting social relevance remains limited ([Fetmawati et al., 2025](#); [Yore, 2018](#)).

Finally, the theme of the ethics of knowledge indicates that the global literature [Kalganov \(2023\)](#); [Munn et al \(2018\)](#); [Stilgoe \(2020\)](#) has expanded the scope of ethics from research integrity to the ethics of knowledge. Indonesian literature [Salam & Ismail \(2025\)](#) has begun to address this issue, but a national ethics forum involving philosophers of science, scientists, and the public has not yet been established. The capacity of research ethics committees also remains limited to human/animal subject protocols, not yet covering epistemic responsibilities and social impacts.

RQ 3. Gaps and Implications for Policy, Higher Education, and Research Ethics in Indonesia

The analysis reveals three critical roles of the philosophy of science in the 21st century: (1) navigating the complexity of nonlinear systems, (2) safeguarding epistemic integrity amid publication pressures, and (3) shaping a forward-looking ethics framework that is integrated from the research design stage.

The implications for Indonesia are transformative. First, national research policy must adopt an epistemically pluralistic evaluation framework, one that goes beyond bibliometric metrics to assess the quality of argumentation, methodology, social relevance, and transformative impact ([Purba, 2025](#)). Second, higher education curricula must integrate the philosophy of science into research methodology, professional ethics, and interdisciplinary seminars, so that doctoral education fosters reflective scientists ([Buckner & Stein, 2020](#)). Third, research ethics committees need to be strengthened with philosophical expertise, so that ethical assessments encompass epistemic responsibility and social impact. A national forum on the ethics of emerging fields of science, such as AI and biotechnology, also needs to be established, involving philosophers of science, scientists, and the public ([Setyawan & Anggera, 2024](#)).

Thus, the philosophy of science in Indonesia must transition from a separate academic discipline to a reflective praxis embedded throughout the entire cycle of knowledge production, validation, and application. This transformation is a prerequisite for building a productive, relevant, and responsible scientific ecosystem.

CONCLUSION

This study concludes that the philosophy of science has undergone significant theoretical development in response to the dynamics of 21st-century knowledge, adopting a new position as “embedded critical reflection.” In Indonesia, awareness

of the relevance of the philosophy of science is reflected in contemporary academic discourse that is critical of reductionism, responsive to technology, and seeks social relevance; however, there remains a gap between this discursive awareness and its internalization within research policy, higher education curricula, and research ethics practices. Therefore, strategic steps are needed, including strengthening research policies through epistemically pluralistic evaluation, integrating the philosophy of science into the *Merdeka Belajar*–Kampus Merdeka curriculum, and enhancing the capacity of research ethics committees with an epistemically ethical perspective. Furthermore, further research is needed to map the epistemological and ethical decision-making practices of Indonesian scientists, while also developing a distinctive Indonesian philosophical model of science by integrating modern science and local wisdom. Although this study is limited to a literature review, the findings are expected to spark substantive dialogue among the philosophy community, policymakers, and higher education practitioners to place the philosophy of science at the center of building a mature, productive, relevant, and responsible knowledge ecosystem in the 21st century.

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Author contribution

Dewi Ratna Bian: data curation, writing-original draft preparation, analysis, **Nurhadia:** conceptualization, visualization, and editing, **Mustamin Giling** methodology.

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The data and the grammatical structure in this article have been validated and verified by English language experts and no AI-generated sentences are included in this article.

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Ethical clearance

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