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Guiding Science and Technology: A Systematic Literature Review on the Role of Philosophy of Science

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Abstract: Philosophy of science has a very essential role in directing the development of science and technology. As a discipline that studies the nature, methods, and limitations of science, philosophy of science helps provide epistemological, ontological, and axiological foundations in the development of various scientific fields. This study aims to examine the role of philosophy of science in shaping scientific paradigms and its impact on the development of science and technology through the Systematic Literature Review (SLR) approach. By analyzing various studies published in the last five years, this study found that philosophy of science not only functions as a conceptual framework for the development of science, but also as an ethical guide in the use of technology. The research findings show that a deep understanding of the philosophy of science can improve the integration between technological innovation and human values, resulting in more responsible and sustainable scientific development. Thus, this study emphasizes the urgency of a philosophical approach in ensuring the direction of the development of science and technology that is in line with the needs of society and the principles of ethics and sustainability.

Keywords: Directing the Development of Science and Technology, Philosophy of Science, Systematic Literature Review

A. Introduction

The development of modern technology is taking place at an extraordinary speed and bringing profound transformations to almost all aspects of human life, that the rapid development of artificial intelligence requires a new ethical framework that integrates human responsibility with technological autonomy (Floridi, 2023). The digital revolution, artificial intelligence, and big data-based systems have changed the way humans interact, work, and acquire knowledge, stating that the digital data revolution has brought about major changes in various fields such as digital health, digital economy and highlighting that artificial intelligence is now a pervasive element in digital society (Emmert-Streib, 2021).

However, behind this progress, ethical and epistemological questions have emerged that are increasingly pressing to be examined. The epistemology-cum-ethics framework emphasizes that human actors remain central in defining, examining, and reviewing the epistemic and ethical values embedded in AI systems (Russo et al., 2024). How moral principles and ethical responsibilities are applied in the context of autonomous and predictive technology, that the use of technological resources in education can weaken the cognitive development of students (Cassinadri, 2024).

Historically, the philosophy of science has focused on how humans construct, assess, and validate knowledge through the principles of logic, observation, and the scientific method. This classical paradigm places humans at the center of truth-making, where the validity of a theory depends on rationality and empirical testing (Anand et al., 2020).

Entering the digital age, new challenges have emerged to the way we understand knowledge. The rise of artificial intelligence (AI), machine learning, and big data-driven systems has transformed the very fabric of knowledge production and validation. Contemporary academics, for example, have argued that rapid advances in deep learning have come at the cost of increasing computational demands. As the use of computing power in cutting-edge AI research grows exponentially, access to those resources is becoming increasingly concentrated in the hands of a few large industry players (Ahmed & Wahed, 2020), Although AI systems are increasingly taking over roles traditionally occupied by human epistemic authorities (EAs), their epistemological status remains unclear (Hauswald, 2025), Generative AI is increasingly being used as an epistemic tool to aid inquiry, expand our knowledge, and generally help us discover new things. AI is already embedded in internet search functions to summarize information and answer user queries without the need to access further websites or news articles. However, generative AI-based models have inherent weaknesses that can hinder their effectiveness as tools to support responsible inquiry (Culture & Humphreys, 2025).

Concurrently, other researchers have suggested that the ongoing digital transformation in society has given rise to what some scholars provocatively call the Algorithmic Age: a time in which human endeavors are increasingly mediated, supported, regulated, determined, structured, and even replaced by algorithms and algorithmic systems (Cech, 2022). Simultaneously, university educators' perspectives on their alignment with AI ethics suggest that activity theory can provide deeper insights into how ethical values are integrated into AI practices. This research highlights the importance of integrating moral principles and ethical responsibilities into technology design, so that innovation is not only efficient but also socially sustainable(Kamali et al., 2024).

Although several studies have noted the importance of philosophy of science, few studies have systematically explored how classical epistemological principles can be

applied to guide the development and implementation of modern technologies, such as AI-based systems and big data. This lack indicates a significant gap in contemporary literature, particularly regarding the integration of epistemological theory and intelligent technology practice. Contemporary studies have explored algorithmic bias, human-algorithm collaboration, and the reliability of AI-generated knowledge, highlighting the growing complexity of modern technology research. However, systematic syntheses connecting philosophy of science with intelligent technology practice are still rare.

Based on this gap, this study aims to explore how the philosophy of science can guide the development and implementation of AI- and big data-based systems ethically and epistemologically. The novelty of this study lies in its attempt to bridge classical epistemological theory with modern technological practice, providing a framework that can integrate human reflective considerations into the design of AI systems. Thus, this study is expected to contribute both to the theoretical understanding of knowledge production in AI and to the practice of responsible technology design. The primary research questions addressed are:

1. How can the principles of the philosophy of science be applied to improve the validity and reliability of knowledge in AI systems?
2. How can the integration of ethical values shape the responsible design and implementation of AI?
3. What are the epistemological implications of human-algorithm collaboration in the context of modern technology research and practice?

B. Methods

1. Research Design

This study uses a Systematic Literature Review (SLR) to explore the role of philosophy of science in guiding modern science and technology, particularly in the context of artificial intelligence (AI) and big data-driven systems. A Systematic Literature Review (SLR) is a research method used to collect, identify, and critically analyze all available research studies (Carrera-Rivera et al., 2022).

2. Literature Search Strategy

Literature searches were conducted on international databases, including Scopus, Google Scholar using a combination of keywords:

a. “philosophy of science”
b. “artificial intelligence”
c. “big data”
d. “ethics”
e. “epistemology”

Inclusion criteria:

a. Peer-reviewed articles in English.
b. Publication between 2020–2025.
c. Focus on the philosophy of science, AI, big data, or technology ethics

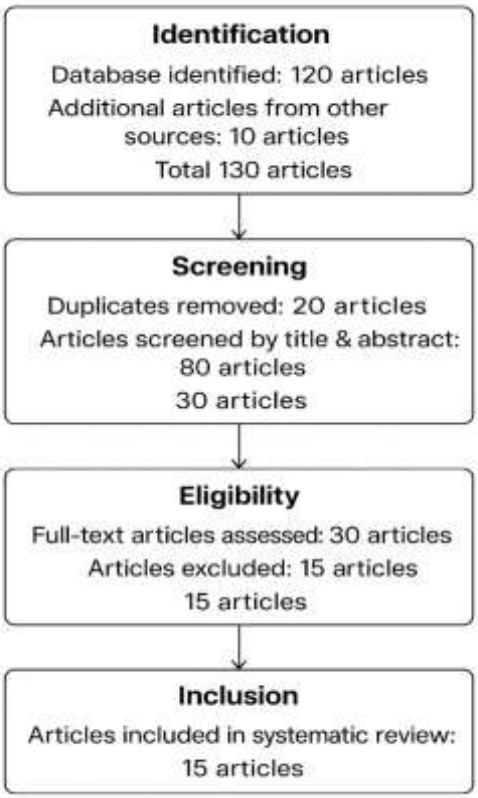
Exclusion criteria:

a. Non-academic articles, editorials, or blogs.
b. Duplicate publication.
c. Articles that do not substantially discuss the role of the philosophy of science

3. PRISMA Flow Diagram

The literature selection process is visualized using a PRISMA Flow Diagram. The PRISMA 2020 flow diagram illustrates the flow of information through the various phases of a systematic review. The diagram maps the number of records identified, included, and excluded, along with the reasons for those exclusions (Rethlefsen & Page, 2022), which consists of four main stages:

1. Identification – articles found through databases and additional sources.
2. Screening – articles are screened based on title and abstract, duplicates are removed.
3. Eligibility – eligible articles are fully checked for eligibility.
4. Inclusion – articles that were ultimately included in the review.



Prisma Flow Diagram

4. Data analysis

The selected articles were analyzed using thematic analysis to guide researchers in producing and reporting methodologically and coherent thematic analyses and to assist reviewers in assessing good practices in thematic analysis research (Braun & Clarke, 2023). To identify, analyze, and report patterns (themes) in the literature. The analysis process is carried out in six stages:

1. Familiarization – read the entire article repeatedly to understand the context and content.
2. Generating initial codes – marking relevant information, ideas, and findings.
3. Searching for themes – grouping the initial code into broader and more meaningful themes.
4. Reviewing themes – review themes to ensure they are representative and consistent with the data; combine or separate themes if necessary.
5. Defining and naming themes – name and define each theme to make it clear and descriptive.
6. Producing the report – organizing findings in a narrative manner, highlighting patterns, contributions, and implications of the philosophy of science in modern science and technology practices.

This approach ensures that the analysis is structured, transparent, and replicable, and generates insights that can serve as a basis for developing theory and practice in the fields of AI and big data.

C. Results and Discussion

The philosophy of science is not merely a theoretical aspect, but also has a real impact on the development of science and technology. The philosophy of science has existed as long as philosophy has existed. The idea that it emerged with neopositivism is historically flawed and detrimental to the development of the philosophy of science itself (Marcos, 2021). Based on the analysis carried out on 15 selected journals that meet the established criteria, the research results are presented as follows.

Table 1. Results of the Review of Mapping Journal Article Data with Related Research

No.	Journal title	Writer	Research purposes	Method	Research results	Key Findings
1	What Can We Learn from the Philosophy of Technology?	(Bate, 2025)	It aims to demonstrate the relevance and importance of the philosophy of technology in the context of current technological innovation and development. It emphasizes that philosophical thinking can help clarify assumptions, improve decision-making, and align innovation with deep human values.	This article uses a conceptual and analytical approach to explore how the philosophy of technology can be applied in innovation practice.	He finds that the philosophy of technology offers tools for clarifying assumptions, improving decision-making, and aligning innovation with deep human values. He also shows that philosophical thinking can help innovation leaders navigate complex technological challenges like AI and the metaverse.	There is a need for integration of moral reflection into the design of new technologies.
2	Big Data and the Little Big Bang: An Epistemological (R)Evolution	(Balazka & Rodighiero, 2020)	This research aims to critique definitions of big data that focus on volume and technological aspects, and to highlight often-overlooked epistemological issues. The authors argue that big data should be understood in a relational context, not simply as large data sets. They also emphasize the importance of considering the power dynamics involved in data production and analysis.	This article uses a conceptual and analytical approach to explore epistemological issues related to big data. The authors analyze commonly used definitions of big data and discuss the implications of approaches that overemphasize volume and technological aspects. They also distinguish between	found that existing definitions of big data often neglect epistemological and social aspects. They showed that data collection is neither neutral nor objective, and that interpretation and knowledge production remain influenced by theory and subjectivity. Furthermore, they identified a new "digital divide" emerging from unequal access to data and technology. This is changing the stakeholders,	Big data shifts epistemology from theory to big data-based predictive models

				nominal and actual access to data and discuss how this affects power dynamics in scientific research.	gatekeepers, and ground rules for knowledge discovery.	
3	The Use of Examples in Philosophy of Technology	(Bantwal Rao, 2022)	Explain the function of concrete examples in the philosophy of technology.	Conceptual study	Presents the importance of examples in understanding technology Empirical examples strengthen normative arguments.	Real-world examples help bridge technology theory and practice.
4	Understanding Philosophical Media: From Philosophy of Technology to the Technologies of Philosophy	(Pezzano & Pavanini, 2025)	Explains how digital media are changing the practice of philosophy and epistemology of technology.	Conceptual & comparative studies	Media is now not just an object, but also a means of producing philosophical knowledge.	Philosophy is evolving into a "technology of thinking" through the integration of digital media.
5	The Scope of the Philosophy of Science: A Review of Philosophical Education	(Hambali et al., 2024)	Reviewing the scope and role of philosophy of science education in the digital era	Literature review and educational analysis	Philosophy of science education is still limited to theoretical aspects	There is a need for integration between philosophy, AI, and ethics in the modern science curriculum.
6	The Epistemological Foundations of Data Science	(Desai et al., 2022)	Provides a systematic and critical review of the open debate in data science epistemology: its foundations, methods, and consequences. Identifies the main domains of	Conceptual analysis: dividing the epistemology of data science into five main domains, comparing	Establishing five major domains in the epistemology of data science: the constitution of data science (what is data science), the types of	Data science is not just a collection of data or statistical techniques, but has an operative and philosophical identity

			data science epistemology that need further exploration.	descriptive and normative positions, reviewing how knowledge is generated, how the "black box" becomes a problem, and the relationship of data science to the philosophy of science more generally.	questions/inquiries identified, the types of knowledge produced, "black box" problems (such as interpretability and explicability), and the relationship to general philosophy of science.	(descriptive + normative) as an epistemic field.
7	The Ethics of AI Ethics. A Constructive Critique	(Heilinger, 2022)	To ethically analyze current AI ethics practices, identify conceptual, substantive and procedural challenges to AI ethics, and propose strategies to make AI ethics practices more comprehensive and equitable.	conceptual study/normative analysis; reflective philosophy study type: compiling critiques of AI ethics literature & practices, reflections on procedures, and propositions of improvement strategies	Several challenges were identified: for example, excessive hype about AI, AI being understood only partially (not as a comprehensive infrastructure), the neglect of structural justice, less inclusive ethics processes & forums, and the lack of integration of independent philosophical/ethical expertise.	Expanding the scope of AI ethics to include dimensions of justice and structural issues; more inclusive and reflective ethical procedures; reforming terminology; understanding AI as part of social infrastructure; considering not only outputs but also processes.
8	Being Blinded by the Concrete – On the Extractivist Blindspot of the Empirical Turn in	(Vandemeulebroucke et al., 2025)	Criticizes that the philosophy of technology especially after the "empirical turn" (focus on concrete technological objects and specific uses/designs) has lost attention to the extractive	Theoretical/conceptual analysis; philosophical critique of the philosophy of technology literature,	Post-empirical turn philosophy of technology tends to focus on concrete technological objects, users/designs/uses, but ignores how these objects	Proposes that the philosophy of technology needs to be expanded not only morally/ethically, but ontologically and conceptually—to include a

	Philosophy of Technology		social environmental context (extractivism) as an important condition in which technological objects emerge.	especially literature representing the empirical turn; polit-economy study of extractive practices	are born through supply chains, material extraction, ecological consequences, and further social impacts.	long history of materials, extraction, non-humans, relations, and environmental consequences.
9	Idealisation and Scientific Literacy in the Governance of Facial Analysis Technologies: Reply To Gentzel	(Walsh, 2025)	Responding to Gentzel's criticisms of facial recognition/facial analysis technologies, particularly Automated Facial Expression Analysis (AFEA), the paper discusses the issue of inferring emotions from facial expressions: that the scientific models underlying these technologies use idealizations and that claims of emotional inference often fail to account for weak scientific evidence and scientific contestation.	This philosophical commentary/essay (reply) is not new empirical research. It utilizes existing literature on ERTs/AFEA, scientific models of emotional expression, and critiques emotional inference, cultural bias, and the use of idealization in the models.	Emotional inference from facial expressions via automated technology relies heavily on idealizations (simplifications) in scientific models; facial expressions alone are not always a direct ("literal") indicator of emotional states, due to culture, context, display rules, etc.	Idealization can be used as a tool to explain how a model/technology works, but also pointing out its limitations is important so that users or regulators are aware that the models are not literal.
10	Does Philosophy Make Less Progress than Other Academic Fields?	(Maslen, 2024)	Assessing whether philosophy has actually made less progress than other academic fields, and whether there are objective measures that can be used to assess "progress" between different disciplines.	A conceptual approach and comparative analysis of metaphilosophical and philosophical literature; reviewing several criteria of progress (problem resolution, level of consensus, epistemic value, conceptual	The analysis shows that there is no objective and universal measure for comparing progress between fields. Philosophy does show less consensus on major questions than science, but this does not automatically mean that philosophy is not progressing. Much progress	The claim that philosophy is "less advanced" cannot be objectively verified because the measures of progress differ between disciplines. Philosophy makes progress in non-empirical ways, such as clarifying concepts, sharpening arguments,

				contribution, practical impact). Using argumentative and evaluative analysis of these indicators.	has occurred conceptually and methodologically.	and developing methods of thinking. Differences in the characteristics of the objects of study and methods lead to differing rates of progress between philosophy and science.
11	Developmental Moral Progress in Technology Research: the Case of the Personalized Parkinson's Project	(Bögner & Figà-Talamanca, 2025)	Demonstrates how a philosophical focus on interactive and dialogical processes in technology research & development can help identify moral progress.	A philosophical and ethical study ("philosophical inquiry") of moral progress literature, moral development theory, and theories of moral motivation	In PPP projects, there is a shift in how developers view research participants; there is an awareness that participants are not just numbers/data, but have their own perspectives and values that need to be considered.	Dialogue and interaction between researchers and research participants are crucial mechanisms for moral progress: they enable reflection, design adjustments, recognition of participants' needs, and redistribution of power. The importance of R&D's role lies not only in the end use of technology but also in determining its moral impact.
12	Digital Replacement of the Dead: A Legitimate Worry?	(Buben, 2025)	It aims to explore and critique the potential replacement of deceased individuals with their digital replicas, as well as the ethical implications of IPCD technology. It emphasizes that while this technology can assist in the grieving process, there are	This article uses a conceptual and analytical approach to explore the ethical issues associated with IPCD. Buben analyzes the existing literature on the use	found that while IPCDs can offer a new way to commemorate the deceased, this technology also poses significant ethical risks. He identified that the use of IPCDs could lead to the replacement of	Philosophy of science & ethics needs moral limits on AI simulations.

			concerns that it could lead to unethical replacement of deceased individuals in the lives of the living.	of this technology in the context of grief and introduces the concept of "replacement" as a key ethical issue. He also discusses the potential for commercial misuse and disrespectful treatment of the deceased.	the deceased in the lives of the living, which could obscure the grieving process and honor the memory of the deceased. Furthermore, there are concerns about the potential for commercial misuse and disrespectful treatment of the deceased.	
13	From What to How: AI Ethics Tools	(Morley et al., 2020)	This research aims to identify and categorize publicly available AI ethics tools and methods to assist ML developers, engineers, and designers in applying ethical principles at every stage of development. This approach is expected to facilitate the application of ethics in practice and highlight areas requiring further development.	This study uses a systematic literature review approach to identify existing ethical tools and methods. These tools and methods are then categorized into a typology that combines five key ethical principles (beneficence, non-maleficence, autonomy, justice, and explicability) with the stages of algorithm development in an	The research findings show that while many ethics tools and methods are available, their distribution is uneven. Most tools focus on the early stages of planning and design, while other stages, such as testing and evaluation, have fewer tools available. Furthermore, many existing tools are still in their early stages of development and not yet ready for widespread use in practice.	AI ethics requires a practical and reflective approach to fit the social context.

				ML pipeline. This typology is designed to help developers practically apply ethics at every stage of development.		
14	Implications of the Philosophy of Science and Scientific Ethics in the Development of Modern Science	Leonelli (2020)	Explain the contribution of philosophy of science and scientific ethics to the development of modern science.	Reflective & conceptual analysis	Philosophy of science and scientific ethics play an important role in maintaining the objectivity and integrity of science.	Integration of scientific philosophy and ethics is necessary so that science does not lose its moral and epistemic orientation
15	Philosophy & Media: A Conceptual Typology	(Pezzano, 2025)	Developing a conceptual typology of the relationship between philosophy and digital media.	Conceptual study & discourse analysis	Media philosophy explains the role of communication technology in the construction of meaning.	Digital media creates new epistemic spaces that challenge the boundaries between fact and interpretation.

The literature review shows that the philosophy of science plays a crucial role in guiding the development and application of artificial intelligence (AI) and big data-based systems, from both epistemological and ethical perspectives (Babushkina & Votsis, 2022). In an epistemological context, AI presents new challenges regarding the validity and reliability of knowledge. Machines can process and analyze large amounts of data at high speed, but this raises questions about how trustworthy the algorithm's output can be. The philosophy of science offers a framework for assessing this credibility, emphasizing the need for critical reflection on the assumptions used in AI inference and decision-making processes. A rigorous validation process, based on the principles of falsification and verification, is essential to prevent the resulting information from being misinterpreted as absolute truth That trust and reliability are important factors in assessing AI output, so human oversight remains essential(Robertson, 2025).

However, some historians argue that reliance on philosophical frameworks may not fully address the epistemic challenges posed by AI. That current epistemology is inadequate for AI-based science because it cannot account for the opaque decision-making of AI systems (Koskinen, 2024). Similarly, highlights that Deep Neural Networks are often epistemically opaque, limiting human understanding and challenging traditional concepts of knowledge validation (Ortmann, 2025). This perspective suggests that the reliability of AI cannot be assessed solely through classical philosophical approaches.

Furthermore, studies show that human-algorithm collaboration produces new, hybrid forms of knowledge. Knowledge is no longer generated solely by individuals, but through complex interactions between humans and computing systems. This has significant epistemological implications: evaluating information quality must consider the social context and subjectivity of the data, as well as the reflective involvement of humans in interpreting AI results. This concept leads to a relational knowledge paradigm, where human-AI interaction becomes an integral part of the knowledge production and validation process.

From an ethical perspective, the philosophy of science provides guidance for designing responsible AI. Applying the values of responsibility, fairness, and transparency helps ensure that technology is not misused or negatively impacts society. Technology ethics emphasizes that AI development must consider long-term consequences, including social, existential, and cultural implications. With this approach, system design not only optimizes technical performance but also upholds moral principles and human well-being.

The literature review also shows that applying the philosophy of science to AI enables the development of adaptive, reflective, and more robust systems. An understanding of critical epistemology helps identify blind spots or algorithmic limitations, while ethical considerations guide sustainable and humane decision-making. Overall, this

integration of epistemological and ethical principles forms a comprehensive framework for AI development, ensuring systems that are technically efficient while also being fair, transparent, and meaningful to users and the wider community.

Thus, the results of the literature review confirm that the philosophy of science is not only a theoretical framework but also a practical guide capable of navigating the complexities of modern AI, bridging the gap between the reliability of knowledge and the moral responsibility in the use of intelligent technology.

D. Conclusion

Based on a comprehensive literature review, this study confirms that the philosophy of science plays a fundamental and multifaceted role in guiding the development and implementation of artificial intelligence (AI) and big data-based systems, both epistemologically and ethically. Key findings demonstrate that classical principles such as validity, objectivity, and falsifiability remain crucial in assessing the accuracy and credibility of algorithmic knowledge, ensuring that human involvement continues to drive knowledge production. Furthermore, the ethical dimension of AI development is strengthened by the integration of core values, including responsibility, fairness, transparency, and human-centered desires, which collectively support the creation of socially responsible and moral AI systems. This review also highlights that collaboration between humans and algorithms produces hybrid forms of knowledge, requiring a relational and reflective epistemology. Such a framework emphasizes that human-machine interactions not only expand the capacity for knowledge creation but also introduce new responsibilities for interpreting, interpreting, and validating outputs. The practical implications of these findings are significant, underscoring the need for responsible innovation, the integration of educational ethics in technology-related disciplines, and the development of AI development policies that prioritize human values over technical efficiency. Furthermore, these findings suggest that addressing epistemic and ethical challenges is crucial to bridging the gap between the technical performance and the broader societal impacts of AI technologies. For future research, it is recommended to conduct empirical studies that apply the principles of philosophy of science across various sectors, including education, healthcare, and governance, and explore adaptive and sustainable models for human-AI epistemic collaboration. In conclusion, philosophy of science serves as a normative and epistemological compass, driving AI development toward outcomes that are not only technically robust but also ethical, socially responsible, and aligned with fundamental human values. By providing a framework for critical reflection, accountability, and ethical oversight, philosophy of science ensures that technological progress aligns with societal well-being, bridging the gap between innovation and its human and social consequences.

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