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DEEP LEARNING EPISTEMOLOGY: A PHILOSOPHICAL PARADIGM OF SCIENTIFIC UNDERSTANDING IN THE ERA OF ARTIFICIAL INTELLIGENCE

Septiana Munggarani[1a*], Yusuf tri herlambang[2b], Yunus Abidin[3c]

[123]Mater of Elementary School Teacher Eduction, Universitas Pendidikan Indonesia, Bandung, West Java, 40625

septianamunggarani17@upi.edu
yusufth@upi.edu
yunusabidin@upi.edu

(*) Corresponding Author
septianamunggarani17@upi.edu

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ABSTRACT
Rapid developments in artificial intelligence (AI) have influenced the way humans perceive, organize, and generate knowledge. In the era of digital technologies and automated decision-making, it is increasingly important to reconsider how knowledge and cognitive processes are formed, particularly when machine learning systems begin to replicate and occasionally surpass certain analytical abilities of the human mind. This study examines the transformation of traditional epistemological concepts through the implementation of deep learning and evaluates its implications for scientific understanding and educational practice. A Systematic Literature Review (SLR) approach was used to analyze recent studies related to epistemology, deep learning, and the philosophy of knowledge within the context of AI. The results of the review show that deep learning not only represents technological innovation but also suggests the potential shift toward a new epistemological orientation in acquiring and validating knowledge. This orientation highlights data-driven reasoning, continuous learning, and the construction of meaning through inferential patterns that resemble human thought processes. Overall, the study indicates that deep learning supports the development of a dynamic model of scientific understanding that encourages a synergy between artificial intelligence and human judgment in shaping meaningful and ethically responsible knowledge.

INTRODUCTION

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In the modern era, the process of learning and knowledge production has undergone a significant transformation, especially with the emergence of deep learning systems (*deep learning)* which is now a major driver in the development of artificial intelligence (*Art Intelligence*, AI). For example, studies of data science epistemology show that data science and machine learning technology have challenged traditional epistemological foundations such as transparency, interpretability, and knowledge justification. In the context of AI, crucial questions arise about how machine systems can generate trustworthy knowledge, as well as how this affects scientific understanding and the position of humans as knowledge subjects. Herlambang (2023) emphasized that technological advances cannot be separated from philosophical reflection, because every digital innovation has implications for the way humans understand and interpret reality. According to him, education and technology have an ontological relationship that affects each other. Technology is not just an aid, but alsoan epistemic suggestion that shapes the way humans think and act in the context of modern knowledge. (Springer., 2022; Undiksha, 2021; Herlambang Y. S., 2024)

Several scholars have examined the epistemological status of machine learning. proposes that machine learning represents a form of knowledge production that progressively detaches itself from human experience and rational decision-making, as its inferential outcomes are generated through algorithmic statistical patterns rather than intentional human cognition (Bai, 2022) . Furthermore, the study of data science epistemology identifies *Black box problems* as a major obstacle in the epistemic justification of automated system outputs. On the other hand, the study (Springer., 2022)*Opacity of deep learning in Scientific Discovery* shows that although the *Deep Learning* Being able to make highly accurate predictions, the openness of its internal processes is a great challenge in the context of scientific epistemology. In the context of Indonesian Education, Herlambang (2024) emphasized that the adoption of artificial intelligence and (Press., 2023)*Deep Learning* in learning is not only technological, but also philosophical. According to him, AI-based learning reflects the paradigm shift in Education from an instructional model to a reflective, collaborative, and participatory model that demands the integration of human values and moral wisdom in scientific practice.. Thus, there is a gap between traditional epistemology that emphasizes knowledge as the result of human rational reflection, and the contentious epistemic reality that emerges from deep learning systems that are computational and autonomous. As affirmed by (herlambang, 2024b)(Herlambang Y. T., 2023b)the emergence of "thinking technology" such as artificial intelligence challenges the boundaries of classical epistemology and highlights the need to build a "technological epistemology," namely a new way of understanding knowledge formed through interactive collaboration between humans and machines. This gap shows the need for a broad philosophical framework to explain the relationship between artificial intelligence, deep learning, and the nature of scientific truth.

Based on the analysis of these gaps, this study asks the question: How are traditional epistemological paradigms affected by the application of *deep learning* and its implications for scientific understanding in the era of artificial intelligence? The purpose of this study is to systematically review the literature related to epistemology and deep learning is examined through the Systematic Literature Review (SLR) method, so that it can be identified as philosophical paradigm changes that occur and novelties that emerge. The novelty of this research lies in the combination of classical epistemological frameworks with the technical and scientific realities of deep learning, as well as efforts to present a new epistemic paradigm that is adaptive to the development of artificial intelligence and relevant to today's educational practice

METHOD

This study uses a research design *Systematic Literature Review* (SLR) because it is considered most appropriate to answer research questions about how traditional epistemological paradigms are affected by the application of *Deep Learning* and its implications for scientific understanding in the era of artificial intelligence. The SLR method allows researchers to identify, evaluate, and synthesize all relevant literature based on criteria that have been set systematically and transparently. As explained by, the use of SLRs should be equipped with tools and best practices

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to ensure the validity and reliability of evidence synthesis. In addition, the comprehensive guide emphasizes that SLR in the field of Education requires standard stages such as the definition of research questions, search strategies, inclusion/exclusion criteria, and clear study selection. As revealed in studies that use SLR to understand (Kolaski, 2023)(Ghamrawi, 2025)(Akmal, 2025)*Deep Learning* in Education, instruments and procedures are described to produce reliable replication.

The design of this research follows four main stages of SLR, namely: (a) the formulation of research questions and the determination of inclusion and exclusion criteria; (b) literature searches on scientific databases (Google Scholar, Scopus, Web of Science, DOAJ) with keywords such as "epistemology", "*deep learning"*, "*artificial intelligence"*, and "*scientific understanding";* (c) the process of filtering articles based on titles, abstracts, and thematic suitability; and (d) thematic analysis of literature that meets the criteria. These procedures are logically sequenced so that the research can be replicated by other researchers. This is in line with PRISMA's guidelines for SLRs that emphasize transparency and reproducibility. Studies on digital competence literature also show that SLR applications in the context of education use a similar strategy.(Domínguez-González, 2025)

The research population encompasses all scientific articles discussing epistemology, scientific understanding, and Deep Learning in the context of assistive intelligence published within the last five years (2020-2025), both in Indonesian and English. The research sample was determined through purposive sampling techniques was carried out using the following inclusion criteria: (a) articles published in peer-reviewed journals; (b) studies relevant to epistemological issues and Deep Learning; (c) publication year between 2020 and 2025; and (d) full-text access available. Articles that did not meet these criteria were excluded from the dataset. This procedure aligns with standard SLR study-selection guidelines as outlined in the University Reading LibGuide(Library, 2025).

Data collection techniques and instrument development are carried out by collecting data through the document analysis with the following steps: (1) identification of keywords and databases; (2) search for the initial literature; (3) recording of search results in the literature table (title, author, year, methodology, main results); (4) filtering articles based on relevance; (5) data extraction using data extraction form (data *extraction from*) which contains variables such as year, field of study, epistemological approach, technology *Deep Learning*; (6) Evaluation of article quality using a literature quality checklist. This instrument is reproducible and described in detail so that the research can be replicated, as suggested by those who use SLR for AI Education literature. In addition, the evaluation of quality and transparency in SLR has also received attention in research that critically examines the methodological aspects of SLR.(Mustafa, 2024)(Muka, 2023)

Data analysis is carried out with a qualitative approach through *Thematic Analysis*. The extracted data are encoded and categorized into several main themes: (a) traditional epistemology paradigms; (b) epistemology *Deep Learning*; (c) human interaction with AI in knowledge production; (d) educational and technological implications. The findings are then synthesized in a narrative and thematic table that describes the shift in philosophical paradigm from traditional to a more computational and reflective epistemic form as found in the AI Literacy study. This analytical framework also adopts the approach found in the ChatGPT review in Education that uses PRISMA-based SLR. (Zhai, 2023)(Chiu, 2024)

To strengthen the theoretical basis and clarify the position of this research in the scientific landscape, an in-depth study was conducted of various articles relevant to the themes of epistemology, *deep learning*, and the integration of artificial intelligence in the context of education and philosophy of knowledge. This literature review was prepared through a systematic literature review (SLR) approach by browsing articles from various national and international journals that are directly related to the focus of the research. This review aims to identify the direction of previous research development, find conceptual gaps, and map the contribution of each work to the development of epistemological paradigms in the era of artificial intelligence. Each article reviewed is summarized based on four main aspects, namely the title and author of the article, a summary of the content and focus of the research, the main results and findings, and its relevance to this research topic.

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In summary, this part of the method provides a fairly complete picture so that research with SLR can be replicated, starting from design, population/sample, data collection, to analysis techniques, so that the results can be trusted and have methodological transparency.

RESULT

The results of the study are presented in the following Table 1, which shows the diversity of approaches and findings from various academic sources that support philosophical analysis of the epistemology of deep learning in the digital age

Table 1. *Systematic Literature Review*

Not	Article Title and Author	Article summary	Results and Findings	Topic Relevance
1	Akmal, M. M. (2025). Systematic literature review (SLR) in the development of deep learning-based learning in the digital era	Review SLR methodology to identify deep learning research trends in the context of digital education.	SLR has proven effective in mapping AI-based learning innovations and finding research gaps.	It became a strong methodological foundation for this research.
2	Anderson, J. (2020). Educational epistemology in the context of machine learning.	Analyze the interconnectedness of epistemology and machine learning in higher education.	AI-based learning expands human reflective abilities if developed ethically.	Provides an epistemic framework for understanding deep learning.
3	Bai, J. (2022). Machine learning epistemology. Philosophy. Sociology	Discuss the epistemological basis of machine learning systems.	AI builds knowledge through algorithms that mimic human intuition	Relevant as the philosophical basis of this research.
4	Casal-Otero, LE (2023). AI Literacy in K-12: A systematic literature review. International Journal of STEM Education	Review AI literacy in primary-secondary education.	AI literacy is important for building a critical digital epistemology from an early age.	Supporting the pedagogical dimension of AI epistemology.
5	Chiu, T. K. (2024). A systematic literature review on ChatGPT in education. Discover Education, 3(24), 1–21.	Examining the application of ChatGPT in education through the SLR approach.	It found the potential of ChatGPT as a reflective learning agent, but it needs ethical supervision.	Supporting discussions about AI as an epistemic subject.
6	Desai, C.B. (2022). Epistemology of data science: Five emerging research domains. Synthesis	Outline five new domains in data epistemology.	Data science demands a new model of justification based on openness and algorithmic transparency.	Relevant to the theme of epistemic opacity in AI.
7	Domínguez-González, M.J.-R.-T. (2025). Teachers' digital competence: The key to the future of education through systematic review.	Analyzing teachers' digital competencies in the AI era.	Teachers play an important role in directing students' digital epistemology.	Supporting the praxis dimension of educational epistemology.

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8	Duede, E. (2022). Lack of clarity of deep learning in scientific discovery. arXiv / Philosophy of Science.	Examining the opacity of AI systems in scientific discovery	Finding that AI often produces decisions that are difficult to explain epistemicly.	Underlying the theme of "epistemic opacity" of this research.
9	Education, BA (2025). Concerns about Big Tech's influence in knowledge formation. BusinessInsider/Wired.	Highlighting the power of tech companies in knowledge formation	Big Tech is shifting academic epistemic autonomy toward algorithmics.	Provide a social context for digital epistemology.
10	Floridi, L. (2022). About the epistemology of data and information. Synthesis	Develop information-based knowledge theory.	Knowledge in the AI era is the result of human-data relations.	Provides a philosophical basis for information epistemology.
11	Ghamrawi, N. A. (2025). A step-by-step approach to systematic review in educational research.	Practical guide to the implementation of SLR in educational research	SLR strengthens the validity of educational research through data traceability.	It is used as a methodological guide for this research.
12	Herlambang, Y. T. (2023). Education and Technology: A Study of Philosophy in Don Ihde's Perspective.	Explain the human-technology relationship in the context of reflective education.	Technology is a medium that mediates knowledge and learning awareness.	Became the philosophical foundation of this research
13	Herlambang, Y. T. (2023b). Epistemology of Technology and Educational Challenges in the Age of AI.	Analyze the epistemological challenges of education due to the dominance of AI.	AI demands a new understanding of the nature of learning and thinking.	Directly relevant to the main theme of the research.
14	Herlambang, Y. T., Setiawati, R., & Yolandha, W. (2023). Technological Transformation in Education in the Era of the Industrial Revolution 4.0.	Reviewing the ethical dilemma of the use of modern educational technology	Concludes that ethics should be the basis for AI integration.	Strengthening the moral side of digital epistemology.
15	Herlambang, Y. T., & Lestari, I. D. (2025). Digital Transformation in Education: A Critical Review in Philosophical Review	Analyze the impact of digitalization on teachers' epistemological reflection.	It was found that the need for rehumanization of educational technology was found.	Relevant to the theme of reflective epistemology.
16	Kitchenham, B., & Charters, S. (2022). Guidelines for performing SLR in software	Classical guidelines of the SLR methodology.	Provide a framework for transparency and replication of research.	Used for justification of research methodology.

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	engineering. Information Technology and Software.			
17	Kolaski, IL (2023). Tools and best practices for systematic reviews.	Discuss SLR devices and best practices.	The use of digital devices improves the accuracy of literature analysis.	Supporting the technical aspects of this research method.
18	Letelier, LM (2021). A systematic review and its epistemological foundation.	Connecting epistemology with SLR logic.	SLR reflects a new form of collective-based scientific knowledge.	Strengthen the theoretical foundation of qualitative-SLR methods.
19	Lmaleidykla (2022). Epistemic opacity and knowledge representation in the AI era.	Highlights the limitations of transparency in AI models.	A new epistemic justification mechanism is needed for intelligent systems.	It is directly related to the theme of "epistemic opacity".
20	Mersha, M. (2024). Explainable AI: Survey needs and methods. arXiv.	Review the need for explainable AI.	*Explainable AI* reinforces epistemic trust and clarity.	Relevant for the theme of openness and justification.
21	Mulyadi, T., & Nopriani, F. (2022). Integration of Epistemological Theory in Educational Management	SLR is about epistemological theory in education management.	The integration of epistemology strengthens teachers' reflection and educational policies.	It becomes the conceptual basis of epistemic management.
22	Mustafa, N. (2024). SLR AI in education: Trends and challenges.	Examine trends in the application of AI in global education.	AI increases efficiency, but poses an ethical dilemma.	Supporting the global context of this research.
23	Putra, S., & Rahman, A. (2021). Philosophy of Digital Education and Modern Epistemological Reconstruction	Explain how digital disruption is changing epistemology.	Collaborative and reflective learning is becoming a new form of epistemology.	In line with the direction of this research.
24	Rifai, I. W. (2025). Integration of Epistemological Theory in Educational Management Practice	Examine the application of epistemological theory in the managerial context of education.	The results show the effectiveness of a reflective approach in educational decision-making.	Provides an empirical basis for the theoretical framework.
25	Samaniego, E., & Torres, L. (2023). Deep learning in education: Concepts, factors, and measurement.	Examine the factors for the success of the implementation of *deep learning* in schools.	Deep learning is effective if it is supported by a reflective culture and learning autonomy.	Supports the theory of epistemic transformation.
26	Sato, M. (2024). Deep Learning as Epistemic Transformation:	Interpreting deep learning as an	AI is shaping a new way of understanding reality.	The main conceptual

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	Rethinking Human Knowledge.	epistemological transformation.		foundation of the research.
27	Shu, J. (2025). Production and dissemination of knowledge in human-AI collaboration.	Examine human-AI collaboration in knowledge production.	Shows a symbiotic model between humans and machines.	Reinforcing the concept of epistemic collaboration.
28	Spring (2022). Data science epistemology: Challenges to transparency.	Review the limitations of data transparency	There is a need to redefine the concept of "truth" in data-driven science.	Relevant to digital epistemological issues.
29	Teng, Q. E. (2022). A survey on the interpretability of deep learning in medical diagnosis.	Review the interpretability of AI in a medical context.	Interpretability improves the reliability of AI models.	Parallel with the issue of epistemic transparency in education.
30	Undiksha (2021). Artificial intelligence in the context of modern educational epistemology.	Examine the role of AI in reflective learning in modern education.	AI is an epistemic agent that stimulates critical thinking awareness.	It is directly relevant to the focus of this research.
31	Zhai, X., & Chen, L. (2023). AI literacy in STEM education: A systematic review	Learning AI literacy in STEM learning	AI literacy builds the epistemic awareness of 21st-century students.	Supporting the theme of pedagogical implications
32	Zhang, L., & Li, X. (2023). Epistemological challenges in AI-based learning.	Review the definition of "knowledge" in AI-based learning.	Knowledge is born from human-machine collaboration.	Relevant to the concept of reflective epistemology.

The results of the analysis of 32 articles that met the SLR criteria identified four dominant themes related to the epistemological paradigm of Deep Learning in scientific understanding: (a) epistemic opacity, (b) transformation of knowledge subjects toward human–machine collaboration, (c) reconfiguration of epistemic justification in the era of Artificial Intelligence, and (d) pedagogical implications requiring new epistemic literacy in higher education and STEM. As stated by (Bai, 2022), machine-generated knowledge is often “beyond human experience and difficult to explain rationally,” leading to the emergence of the Epistemology of Machines. Supporting this, (Desai, 2022)notes that data science and Deep Learning introduce "epistemological challenges at the level of scientific justification and credibility of knowledge." In the educational context, (Samaniego, 2023)emphasizes that Deep Learning operates in higher-order thinking processes and triggers cognitive transformation in learners, thereby requiring a more reflective epistemological approach.

Table 2. Summary of findings based on key themes

Tema utama	Number of articles	Presentase %
Epistemic opacity	12	37,5

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Transformation of knowledge subjects	9	28,1
Artificial Intelligence (AI)	7	21,9
Pedagogical implications	4	12,5
Entire	32	100.0

This table shows that the issue of epistemic opacity is the most dominant in the literature. A total of twelve articles high light *Black box problems* in Deep Learning systems that complicate the process of scientific justification. Articles in this category discuss the limitations of transparency in deep learning inference and how these limitations challenge the traditional epistemic structure of science. Such studies highlight that (Floridi, 2022) and the (Duede, 2022)*Black box problems* raises ethical and philosophical dilemmas regarding the validity of scientific knowledge. (Desai, 2022) further explains that many Deep Learning algorithms produces highly accurate predictive outcomes but cannot be causally explained, thereby challenging traditional epistemological models.

Nine articles indicate that humans are no longer the sole subject of knowledge, but part of a human–machine collaborative system. This theme highlights the shift in the position of humans from *knowledge creators* to *epistemic collaborators* with AI. (Herlambang Y. T., 2023b) confirms that in the AI era, human subjects undergo an epistemological redefinition in the way they think and participate in the production of knowledge. (Bai, 2022)reinforces this by stating that the emergence of *machine epistemology* stems from the inability of humans to fully understand the internal learning processes of AI systems. Research by (Chiu, 2024)emphasizes that the integration of AI-based learning systems is reshaping the epistemic structure within the classroom. Similar studies by (Akmal, 2025) show that *Deep Learning* expand the human capacity to think reflectively thinking through a continuous Feedback loop between humans and algorithms.

Seven articles in this review address the changing criteria of epistemic justification in science. The studies reveal that within AI-based learning environments, validity is no longer measured solely by empirical truth, but also by the system's ability to generate *adaptive reasoning* (Zhai, 2023). The report also found that digital education demands a redefinition of reliability criteria in the context of knowledge automation systems. These findings of this study expand the existing literature by emphasizing that epistemology . (Domínguez-González, 2025)These results support the idea of *Technological Epistemology* and strengthen the view that the epistemology of modern science is shifting toward a post-human paradigm in which humans and machines are interdependent in the construction of knowledge (Herlambang Y. S., 2024).

Relationship with Expectations and previous research.

These results are in line with the expectation that *Deep Learning* will raise epistemological challenges (e.g the "black box" problem) and that SLR as a method itself has an epistemic basis that needs to be questioned. For example, an article discussing the epistemological basis of SLR reminds that "although SLR is often considered a high form of scientific evidence, there is criticism that they rarely delve into their epistemological foundations." Thus, this study supports the previous literature but expands on it through specific themes on epistemological combinations + Deep Learning + AI.(Letelier, 2021)

Compatibility or contradiction to the theory of Epistemology

In terms of classical epistemological theories (empiricism, rationalism, constructivism) that are dominant in the educational literature, the results show that the framework less sufficient to explain the phenomenon *Deep Learning* as an agent of knowledge. An SLR study in education management confirms that the most commonly used epistemological theories are empiricism, rationalism, constructivism, and pragmatism. But not many explicitly discuss the epistemology of technology or machines. Thus, the results of this study challenge classical theories and support

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the idea that we need a new epistemic paradigm that incorporates elements of machines, human-machine collaboration, and algorithmic transparency(Rifai, 2025)

The findings suggest that although much of the SLR literature is done on *deep learning* from a technological and application perspective, the amount that addresses epistemological aspects (who knows, how to know, and based on what knows) is still limited. This shows a significant gap: the technical and applicative literature may be numerous, but the literature that relates to the epistemology of science is lacking. Thus, this study underscores the importance of developing an epistemic framework that **includes** *deep learning* as a knowledge entity, and not just as a tool.

DISCUSSION

The SLR results show four dominant themes: (1) epistemic opacity or *Black Box Deep Learning*; (2) the transformation of the role of human-machines as co-producers of knowledge; (3) changes in the criteria for scientific justification; and (4) pedagogical implications that demand new epistemic literacy. These findings illustrate a shift from a single-human subject-centered epistemology to a more ecosystem epistemology, in which computational agents help shape what counts as "knowledge." This interpretation is consistent with the idea that machine learning is not just a tool, but also a process of knowledge production that has unique characteristics. A highly predictive output that is often causally inexplicable to humans. . Based on SLR's findings, the issue of opacity does not necessarily eliminate the scientific value of AI outputs; Instead, many researchers emphasize that the role of (Bai, 2022; Desai, 2022)*Deep Learning* often in *context* the process of scientific discovery (e.g., the context of discovery vs. the context of justification), so that the output of the machine can be the basis of a hypothesis even though the mechanism is not yet fully understood.(Duede, 2022)

Our findings confirm the results of previous studies on the challenges of interpretability and the need for XAI (Explainable AI). Recent surveys and reviews show a surge in XAI and interpretability research that seeks to address the technical opacity of the model *Deep Learning* (Teng, 2022; Mersha, 2024)However, while the engineering literature focuses on technical solutions (e.g., saliency maps, surrogate models), the epistemological literature demands a broader understanding: how machine knowledge is positioned in the scientific cycle and how the truth/justification criteria should be redefined. On the educational side, the findings on the need for epistemic literacy are in line with the study of AI-literacy which emphasizes that students need to understand not only how to use AI, but also how to assess AI claims and digital knowledge sources. Differences arise at the practical level: the pedagogical literature discusses a lot of curriculum and competencies, but little integrates in-depth epistemological discussions about the state of knowledge generated by machines.(Desai, 2022; Duede, 2022) (Zhai, 2023; Casal-Otero, 2023)

The epistemological transformation in education management in the era of artificial intelligence shows that technology is not only a tool, but also shapes the way of thinking and understanding knowledge. In this context, the role of educators is no longer just as a conveyor of information, but a facilitator who is able to navigate the complexity of digital and the morality of technology use. This is in line with the view that the transformation of technology in education in the Industrial Revolution 4.0 presents a philosophical dilemma between technological efficiency and human values. Therefore, today's education must focus on developing digital literacy based on ethics and epistemic responsibility so that technology can be used wisely and meaningfully in learning.(Herlambang Y. T., 2023)

The development of artificial intelligence requires the education system to revisit its epistemological foundations. Digitalization not only changes learning methods and media, but also shifts the position of teachers as the only source of knowledge to a new role as a facilitator of critical thinking. In this case, it is explained that digital transformation in education must be seen as a philosophical process, not just a technological phenomenon. They emphasized the importance of deep reflection on human values that are the basis for the learning process so that students do not lose their moral orientation in the midst of the rapid flow of technology.(Herlambang Y. T., 2025)

This new paradigm shifts the position of humans from a single subject of knowledge to part of an intellectual ecosystem involving machines and data. In this transformation, this transformation requires humans to maintain human values and ethics in managing technology, so that the learning process remains on the side of the critical and

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reflective development of students. Thus, epistemology (Herlambang Y. S., 2024)*Deep Learning* It can be understood as a form of cognitive collaboration between humans and intelligent systems in building knowledge.

Theoretically, The results challenge the firm separation between the "context of discovery" and the "context of justification" in the philosophy of classical science; AI forces us to see the process of discovery, verification, and justification as an interdependent series involving machines as epistemic actors (Duede, 2022). Therefore, It is necessary to develop a theory of technological epistemology that includes: (a) the characteristics of computational outputs; (b) the dominating role of statistical inference; and (c) reliability criteria that go beyond mere interpretability.

Viewed from a practical point of view, For researchers and education practitioners, the implications are real: the curriculum must include critical literacy about how AI generates claims, how to assess model reliability, and when to trust algorithm outputs. In the realm of research, the scientific community should develop more stringent standards for reporting AI experiments (e.g. dataset documentation, architecture, interpretability metrics) so that AI outputs are easily evaluated in a scientific context. From a policy and ethical point of view, it is clear that the dominance of commercial and Big Tech models in the provision of generative models also poses a risk of epistemic monopolies (Hart-type concerns): the dependence of educational institutions on closed platforms can undermine academic epistemic independence. Therefore, regulation, open dataset access, and transparency policies are important. (Zhai, 2023; Chiu, 2024)(PRISMA, 2020; Kitchenham, 2022) (education, 2025)

Research Limitations**:** (1) Time and language scope**:** The SLR limits the period 2020–2025 and focuses on English and Indonesian literature it is likely that relevant studies in other languages are missed. (2) Quality and heterogeneity of studies**:** Samples include theoretical, empirical and peer studies; Methodological heterogeneity makes quantitative generalizations difficult. (3) Publication bias**:** Focusing on indexed journals tends to ignore relevant white papers, policy documents, or industry practices. (4) Focus on academic literature**:** Industrial practices (e.g., large production models) can have praxis implications that have not been fully explored in the academic literature. Acknowledging these limitations opens up space for broader and multi-lingual further work.(Muka, 2023; Kitchenham, 2022)

Suggestions for Further Research**:** The suggestions that I can give for further research based on the results and limitations of the research are**:** Human–machine collaborative empirical research: an experimental study that observes the process of scientific discovery when humans work alongside models *Deep Learning* to assess the relative role of machine 'evidence' in scientific justification (Duede, 2022; Shu, 2025) **.** Development of a technological epistemological framework: interdisciplinary studies (philosophy, computer science, education) to formulate new epistemic criteria that are inclusive of machine output (Desai, 2022; Bai, 2022). Interventional pedagogical research**:** test the epistemic-AI literacy curriculum at different levels of education to measure changes in students' critical capacity to AI claims. . (Chiu, 2024; Zhai, 2023)Reporting standards and reproducibility**:** development of AI experiment reporting guidelines in the field of science to make outputs easier to evaluate.(PRISMA, 2020; Kitchenham, 2022)

CONCLUSION

This study illustrates that the epistemology of deep learning is a rapidly evolving field with significant implications for how humans understand, produce, and evaluate scientific knowledge in the era of artificial intelligence. The findings show that the presence of deep learning does not merely introduce technological innovation, but also reshapes the epistemological paradigm from a human-centered model toward a collaborative model in which humans and machines jointly participate in knowledge production. In the fields of education and philosophy of science, this shift highlights the urgency of developing new perspectives on learning and critical thinking, including the strengthening of epistemic literacy—the ability of teachers and students to assess, interpret, and reflect on algorithm-generated information so that human judgment remains central.

In summary, this research contributes to the ongoing discourse by expanding the boundaries of classical epistemology to incorporate the epistemic agency of machines and collaboration between humans and artificial intelligence. Practically, the study provides insights for curriculum development that emphasizes epistemic literacy

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and awareness of technology in learning environments. Nevertheless, this research has limitations, including a restricted study period that covers literature only up to 2025 and a focus primarily on the domains of education and philosophy rather than the broader social, cultural, or political dimensions of knowledge.

These limitations pave the way for further investigation. Future studies are recommended to explore empirical interactions between humans and machines in knowledge production and to construct a more comprehensive framework of technological epistemology. Cross-disciplinary collaboration between philosophy, education, computer science, and ethics is essential to address the fundamental question of who or what can be considered a "knower" in an increasingly algorithm-mediated world. With continued research, the study of deep learning epistemology has the potential to meaningfully inform the ethical, scientific, and educational direction of artificial intelligence development without overstating its role or diminishing human values.

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