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Enhancing Students' Critical Thinking Skills through Philosophy of Science: An Integrative Perspective of Ontology, Epistemology, and Axiology

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Abstract. This study investigates how the philosophy of science contributes to enhancing students' critical thinking skills, focusing on its three foundational dimensions: ontology, epistemology, and axiology. While previous research has widely examined strategies for teaching critical thinking and the use of philosophical perspective in education, limited attention has been given to integrating these three philosophical dimensions into a single analytical framework for science education. To address this gap, a systematic literature review was conducted using academic journal articles, books, and empirical studies related to philosophical inquiry and critical thinking development. The findings reveal that ontological perspectives encourage students to question the nature of scientific reality and examine underlying assumptions, while epistemological insights help them understand how knowledge is constructed and justified, thereby strengthening analytical and reflective thinking. Axiological considerations further support students in recognizing the ethical and value-laden aspects of scientific inquiry, which guide them toward responsible and well-reasoned judgments. The novelty of this study lies in its integrative framework that unifies ontology, epistemology, and axiology to explain how philosophical literacy can systematically foster critical thinking in science education. This contribution provides a conceptual foundation for designing instructional approaches that explicitly incorporate philosophical inquiry to enhance students' critical thinking abilities.

Keywords: critical thinking, philosophy of science, ontology, epistemology, axiology

INTRODUCTION

Education plays the vital role in life, as it enables people to gain knowledge and transform their way of thinking. In Indonesia, efforts to enhance the quality of education are ongoing and continue to envolve in line with the changing times. As educational reforms continue to advance in response to the evolving demands of 21st century, it is imperative that these efforts prioritize the cultivation of critical thinking skills, which are essential for fostering analytical reasoning, informed decision-making, and lifelong learning.

Critical thinking encompasses mental operations such as reasoning, evaluation, classification, deduction, and induction (Hidayat & Sari, 2019; Kd Urip Astika et al., 2013). Despite numerous studies on critical thinking in science education, research often addresses philosophical dimensions in isolation. For instance, Hakim & Talib (2018) focus primarily on epistemological aspects, whereas Alfiyanti et al. (2023) emphasize axiological considerations. Yesasri et al. (2023) highlight the role of ontological reflection but do not integrate it with the other dimensions.

Furthermore, the urgency of integrating philosophy into science education is evident from current trends showing a decline in students' analytical reasoning in STEM subjects, both nationally and globally Changwong et al. (2018). Students often struggle to connect scientific knowledge with ethical consideration of societal relevance, highlithing the need for a framework that combines cognitive, reflective, and ethical dimensions.

Therefore, this study aims to examine the extent to which the philosophy of science can enhance students' critical thinking by integrating ontology, epistemology, and axiology, providing both a conceptual foundation and practical insights for science education.

METHOD

This study employs a qualitative approach using a library research method. This methodological choice is appropriate because the primary objective of the research is to analyze conceptually how the philosophy of science—particularly the dimensions of ontology, epistemology, and axiology contributes to the development of students' critical thinking in science education. A qualitative and interpretative approach allows for an in-depth examination of meanings, concepts, and theoretical relationships found in existing scholarly works. The unit of analysis in this study consists of academic discussions, conceptual arguments, and empirical findings related to the philosophy of science and critical thinking skills in science education. The focus of the analysis is directed toward identifying how ontological, epistemological, and axiological perspectives are conceptualized in the literature and how these philosophical dimensions are linked to the cultivation of students' critical thinking abilities.

Data sources used in this research are entirely secondary and include peer-reviewed journal articles, academic books, and relevant literature in the fields of philosophy of science, science education, and critical thinking. The literature was obtained from academic databases such as Scopus, ERIC, and Google Scholar. The selection of sources was guided by their relevance to the research focus, theoretical contribution, and credibility within the academic discourse. Data collection was conducted through documentary study techniques, involving systematic searching, reading, selection, and organization of relevant texts. The researchers carefully reviewed the selected literature to identify key concepts, arguments, and findings related to the integration of ontology, epistemology, and axiology in science learning contexts.

Data analysis was carried out through three main stages: data reduction, interpretation, and conceptual synthesis. In the data reduction stage, the literature was screened to extract essential ideas and themes directly related to philosophy of science and critical thinking. The interpretation stage involved analyzing these themes within their educational and philosophical contexts, with particular attention to how each philosophical dimension supports critical thinking development. Finally, the conceptual synthesis stage aimed to integrate the findings into a coherent analytical framework that explains the collective role of ontology, epistemology, and axiology in fostering holistic critical thinking in science education.

Through this analytical process, the study provides a comprehensive understanding of the philosophical foundations that can support the development of students' critical thinking skills and offers a conceptual basis for integrating philosophy of science into science education practices.

RESULTS AND DISCUSSION

Result

The literature review reveals a consistent pattern in how the philosophy of science contributes to the development of students' critical thinking in science education. Across the analyzed studies, ontology appears as a foundational dimension that encourages students to question the nature of scientific reality and examine underlying assumptions. Yesasri et al. (2023) report that the use of historical debates in science classrooms enables students to critically reflect on scientific concepts, uncover implicit assumptions, and assess the coherence of ideas. Similarly, Ariwinata & Fatimah (2025) show that connecting scientific topics with broader societal contexts provides opportunities for students to analyze both scientific and social dimensions of knowledge. Hakim & Talib (2018) further demonstrate that ontological reflection supports students' analytical awareness by helping them distinguish between observable phenomena and theoretical constructs, leading to deeper engagement with scientific content.

Findings related to epistemology indicate that understanding how scientific knowledge is constructed, justified, and validated is strongly associated with higher-order reasoning and reflective thinking. Anggraini & Fitrisia (2025) find that debate-based activities and structured argumentation improve students' ability to internalize scientific reasoning standards and critically assess evidence. Kelly and Licona (2018) show that engagement in epistemic practices—such as modeling, experimentation, and peer evaluation—supports students in evaluating the reliability of claims and developing systematic thinking habits. In addition, Hakim & Talib (2018) report that inquiry-oriented learning grounded in epistemological understanding strengthens students' capacity to interpret data critically, identify bias, and distinguish between justified and unjustified knowledge claims.

The reviewed literature also highlights the role of axiology in shaping critical thinking through ethical and value-based reflection. Alfiyanti et al. (2023) and Munte (2024) report that examining the societal and

moral implications of scientific developments fosters students' sense of responsibility and ethical reasoning. Sutriani et al. (2024) show that problem-based learning using real-world issues encourages students to reflect on social consequences and increases awareness of the broader impact of science. Ariwinata & Fatimah (2025) further indicate that value-oriented discussions integrated with science content enhance students' ability to evaluate scientific actions not only in terms of accuracy, but also in terms of social relevance.

Discussion

The results indicate that ontology, epistemology, and axiology each contribute distinct yet complementary roles in fostering students' critical thinking. Ontology functions as the entry point by encouraging students to question assumptions about scientific reality, while epistemology provides the cognitive tools necessary for evaluating evidence and constructing justified knowledge. Axiology, in turn, extends critical thinking beyond cognition by embedding ethical and value-based considerations into scientific reasoning. This alignment suggests that critical thinking in science education is not a single-dimensional skill, but a complex process that integrates analytical, reflective, and moral judgment.

Integrating ontology, epistemology, and axiology into one framework provides a new insight for existing academic work. Previous studies have generally examined scientific or philosophical aspects in isolation (e.g., Duschl & Grandy (2013); McComas (2017), without demonstrating how these dimensions interact to shape students' critical thinking skills. In contrast, the present study highlights the importance of viewing ontology, epistemology, and axiology as interrelated components that collectively influence how students reason, evaluate evidence, and make judgments in science learning. This integrative perspective aligns with broader educational views articulated by Angraeni & Ismail (2016), Pahmi et al. (2024), and Yesasri et al. (2023), all of whom emphasize the central role of philosophical inquiry in enhancing educational quality and strengthening teacher professionalism. Furthermore, by situating these philosophical dimensions within the context of curriculum and instructional design, this study supports Saifuddin & Khoirii (2024) argument that philosophical foundations are essential for developing coherent and impactful educational systems.

The synthesis of findings demonstrates that integrating ontology, epistemology, and axiology into a unified framework offers a more holistic approach to cultivating critical thinking. While previous studies often addressed these dimensions separately (Alfiyanti et al., 2023; Hakim & Talib, 2018), the present review shows that their integration supports a form of critical thinking that goes beyond cognitive proficiency to include reflective and ethical reasoning. Moreover, this integrative framework has the potential to address persistent instructional challenges in science classrooms, such as content-heavy curricula and predominantly teacher-centered learning practices Ahmatika (2017). By framing learning activities through philosophical inquiry, educators can create spaces where students are encouraged to question assumptions, validate evidence, and consider ethical implications within authentic scientific contexts.

From a pedagogical perspective, integrating philosophical inquiry into science instruction promotes not only analytical reasoning but also collaborative learning and reflective dialogue. Epistemologically grounded activities, such as debate and evidence-based problem solving, are strengthened when students are simultaneously encouraged to examine underlying assumptions (ontology) and consider ethical implications (axiology). Consequently, embedding these philosophical dimensions into science curricula can transform traditional instruction into a more meaningful and dynamic learning process that systematically fosters holistic critical thinking.

CONCLUSIONS AND SUGGESTIONS

Conclusions

This study demonstrates that the philosophy of science—through ontology, epistemology, and axiology—significantly enhances students' critical thinking in science education. Ontological reflection fosters questioning of scientific reality, epistemological practices strengthen evidence-based reasoning, and axiological perspectives guide ethical and value-conscious judgment. By integrating these dimensions into a unified framework, science education can cultivate holistic critical thinking that transcends mere cognitive skills to include reflective and ethical capacities.

Suggestions

Based on the findings of this study, several suggestions can be proposed for future educational practice and research. First, science educators are encouraged to incorporate explicit philosophical components into their teaching, including discussions on the nature of scientific knowledge, critical examination of underlying assumptions, and evaluation of ethical implications in scientific inquiry. Learning activities that engage students in argumentation, inquiry-based problem solving, and reflective dialogue can further support the development of critical thinking grounded in philosophical understanding.

Second, curriculum developers should consider integrating ontological, epistemological, and axiological perspectives into science learning modules to ensure that philosophical literacy becomes an integral component of scientific literacy. This integration may be realized through contextualized learning materials, the inclusion of philosophical questions, or the use of real-world scientific issues that stimulate deeper analytical and reflective thinking among students.

Finally, further research is recommended to explore empirical approaches for examining the impact of philosophical instruction on students' critical thinking skills. Studies employing classroom interventions, qualitative analyses of student reasoning, or mixed-method designs may provide more robust evidence regarding the effectiveness of integrating philosophy of science into science education. Such research can contribute to the development of more comprehensive instructional models that align philosophical inquiry with the goals of contemporary scientific learning.

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