International Journal of Social Science, Educational, Economics, Agriculture Research and Technology (IJSET) | ISSN (e) : 2827-766X
Volumes 4 No. 8 (2025)

INTEGRATION OF PHILOSOPHY OF SCIENCE AND SCIENCE AND TECHNOLOGY IN SCIENCE LEARNING: TOWARDS CRITICAL AND REFLECTIVE SCIENCE EDUCATION

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Received : 21 May 2025	Published : 14 July 2025
Revised : 29 May 2025	DOI : https://doi.org/10.54443/ijset.v4i8.843
Accepted : 17 June 2025	Link Publish : https://www.ijset.org/index.php/ijset/index

Abstract

The rapid development of Science and Technology (Science and Technology) in the era of Industrial Revolution 4.0 and Society 5.0 demands learning of Natural Sciences (IPA) that not only emphasizes cognitive aspects, but also develops critical thinking skills, reflective, and ethical awareness of students. However, the practice of science learning in Indonesia still faces challenges in the form of the dominance of the rote approach and the lack of integration of the philosophical dimension and the value of science and technology. This study aims to analyze the integration of the philosophy of science and the use of science and technology in science learning and its contribution to strengthening students' critical and reflective thinking skills. The method used is Systematic Literature Review (SLR) by analyzing 15 selected scientific articles from a total of 25 articles obtained through a systematic selection process on academic databases. The results showed that philosophy of science strengthens students' understanding of scientific processes that are critical and tentative, while science and technology act as contextual media that can enrich the science learning process. The integration of both is effective through reflection-based learning models, socioscientific issues, and scientific ethics. This study recommends strengthening science learning that is integrative and holistic to support the achievement of 21st century competencies and the implementation of the Merdeka Curriculum substantively.

Keywords: ***philosophy of science, science and technology, science learning, critical thinking, reflective thinking, science literacy.***

INTRODUCTION

The development of Science and Technology (Science and Technology) in the era of the Industrial Revolution 4.0 and Society 5.0 has had a significant impact on almost all aspects of life, including the world of education. The Industrial Revolution 4.0 which is characterized by the convergence of physical, digital, and biological technologies requires human resources to have cross-disciplinary competencies, critical thinking skills, the ability to solve complex problems, and adaptation to rapid change (Rahman, et al., 2023). On the other hand, the concept of Society 5.0 emphasizes the importance of humanistic use of technology, integrating big data, artificial intelligence (AI), and the Internet of Things (IoT) to improve human welfare (Ayuningtyas, A. A. (2023). The context of the development of science and technology requires the education system, especially the learning of Natural Sciences (IPA), to no longer be merely oriented towards cognitive mastery of scientific concepts, but must also develop students' critical thinking, reflective, problem-solving, and ethical awareness of the implications of science and technology in life (Ristiani, et.al., 2025).

However, science learning at various levels of education still faces serious challenges. Many learning processes are still dominated by the *rote learning* approach and mere transfer of information, so that students lack a deep understanding of the scientific process. Science learning ideally not only emphasizes mastery of facts, but also an understanding of the nature of science as knowledge that is tentative, develops, and is built through a continuous testing process (Ristiani, et al., 2025). This challenge also indicates a gap between learning practices in the field and the direction of national education transformation that has been formulated by the government. This also shows that

science learning has not fully supported the direction of national education policy as stipulated in Permendikbudristek No. 12 of 2024 concerning Curriculum in Early Childhood Education, Primary Education Level, and Secondary Education Level, which emphasizes the importance of strengthening character, critical thinking, reflective, and learning that is relevant to the context of real life. However, philosophical dimensions such as epistemology, ontology, and axiology in science learning are still not explicitly prioritized in educational practices in schools, which leads to limited student understanding of how scientific knowledge is constructed, the nature of the reality studied, and ethical values and responsibilities in the practice of science (Lestari, et al, 2023). In addition, students' awareness of social and ethical issues, as well as the impact of modern technology in the context of the application of science is also still relatively low (Hariyono, et al., 2024).

In this context, the integration of philosophy of science in science learning becomes important and strategic. Philosophy of science provides a foundation for students to understand how scientific knowledge is systematically built, validated and tested through observation, experimentation and rational discussion (Naksabandi, et al, 2025). Through this integration, learners not only acquire scientific knowledge, but are also able to develop critical thinking skills, identify the reliability of information sources, and consider the ethical implications of the application of science and technology (Darmawan et al., 2025). On the other hand, the development of science and technology itself can be utilized as a source of innovation in science learning, for example through virtual laboratories, experimental simulations, artificial intelligence, and big data-based learning (Ansya, Y. A. U., & Salsabilla, T., 2025), which provides opportunities for students to conduct broader and more meaningful scientific exploration.

However, the use of science and technology in science learning also brings new challenges, especially related to ethical aspects, data security, algorithmic bias, and the digital divide. Several issues such as algorithmic bias, autonomous system security, and inequality of technology access are serious concerns in the development of technology-based learning (Front, C., 2025). In addition, inequality in the mastery of digital literacy among students and teachers also affects the effectiveness of technology application in science learning (Firdaus et al., 2024). Therefore, the integration of the philosophy of science and the utilization of science and technology in science learning is expected to be able to produce a generation of young scientists who not only master the concepts of science, but are also able to think critically, reflectively, and have social and ethical awareness in facing the dynamics of the development of science and technology. The synergy of these two aspects is very relevant in efforts to strengthen scientific literacy, higher order thinking skills, and 21st century skills. However, studies that explicitly explore the integration between philosophy of science and the use of science and technology in science learning in Indonesia are still relatively limited. In fact, this approach has the potential to make an important contribution in shaping a more critical and reflective science education. Thus, this study aims to critically analyze the integration of philosophy of science and the use of science and technology in science learning, as well as evaluate its contribution in developing students' critical and reflective thinking skills.

METHOD

This research uses a qualitative approach with the *Systematic Literature Review* (SLR) method. The selection of this method is based on its ability to provide a structured, comprehensive, and transparent approach to identifying, selecting, and synthesizing relevant literature (Yusuf, et al., 2024). Through SLR, researchers can gain a deep, comprehensive, and *evidence-based* understanding, which is in accordance with the needs of the study of the integration of philosophy of science and science and technology in science learning. According to Rahmah et al. (2024) the research procedure was carried out through several systematic stages, namely: (1) systematic literature search on academic databases such as Scopus and Web of Science; (2) screening articles based on title, abstract, and full content according to predetermined inclusion and exclusion criteria; (3) data extraction from articles that pass the selection; and (4) qualitative synthesis to produce conclusions that are evidence-based and relevant to the focus of the study. By using this approach, the research is expected to make a significant contribution to the integrative understanding between philosophy of science and science and technology in the context of science learning, as well as strengthen the theoretical and practical foundations through the synthesis of previous research results.

The purpose of this research is to answer several important questions, among others: how philosophy of science plays a role in supporting the development of science and technology in science learning, what models and strategies have been applied in integrating philosophy of science and science and technology, and how the integration contributes to strengthening scientific attitudes, critical thinking skills, and ethical values in science education. This SLR process was conducted through several systematic stages. First, a literature search was conducted on various scientific databases such as Google Scholar. The keywords used in the search included "philosophy of science", "science education", "integration of philosophy in science learning", "ethics in science education", "science and

technology in learning", and "critical thinking in science education". Next, screening was conducted based on inclusion and exclusion criteria. The inclusion criteria included scientific articles published between 2021 and 2025, written in Indonesian or English, and discussing the topics of philosophy of science, science and technology, and science education in an integrated manner. Meanwhile, the exclusion criteria include non-scientific articles, not peer-reviewed, or only discussing one aspect without integration.

The next step was a stepwise literature selection process. In the first stage, screening was conducted based on titles and abstracts to initially identify the most relevant articles. The second stage involved examining the full-text of to assess the suitability of the article content to the focus and objectives of the study. Finally, a final selection of articles that met the criteria was made for more in-depth and systematic analysis. From a total of 25 articles collected, 15 articles met the criteria and were used as the main sources in this study. The selection of these 15 articles was based on the fulfillment of all inclusion criteria as well as the diversity of contexts and approaches, thus representing the spectrum of relevant literature (Wibowo, 2021). The data obtained were analyzed using a thematic analysis approach, namely by grouping findings based on main themes such as the concept of philosophy of science in science education, integration of science and technology values in learning, reflection-based and ethical learning models, and the contribution of this integration to the development of scientific character and critical thinking skills of students. This analysis is then organized in the form of a narrative synthesis to build a coherent and relevant understanding of the problems studied.

RESULTS AND DISCUSSION

Based on the results of a systematic review of 15 scientific articles published from 2021 to 2025, a deep understanding of the importance of integration between philosophy of science and science and technology in learning Natural Sciences (IPA) is obtained. This integration not only adds a scientific dimension that is reflective and critical, but also responds to the needs of 21st century education which demands mastery of science in a holistic, contextual, and valuable manner

1. Philosophy of Science as a Basis for Critical Thinking in Science Learning

Philosophy of science contributes greatly to strengthening critical and reflective thinking dimensions in science learning. The study by Haki et al. (2022) shows that learners' understanding of epistemology and scientific logic helps them to evaluate science claims rationally and not dogmatically. This is particularly important in today's information age, where the flood of information demands the ability to sort out the truth based on scientific methods and arguments. This approach supports the view that science is not merely a collection of facts, but also an intellectual process involving assumptions, interpretations, and justifications (Ekawati et al., 2024). Therefore, the integration of philosophy of science in learning allows students to understand how science develops through a critical process and is open to revision based on evidence.

2. Utilization of Science and Technology as Media and Contextual Materials

The results of the study also show that Science and Technology (Science and Technology) has become an important element in science learning, both as a learning tool (for example through digital laboratory simulations, Augmented Reality applications, or science-based LMS platforms) and as contextual teaching materials associated with the latest technological developments (Rachmadtullah et al., 2022). However, in practice, the utilization of science and technology is often technical-instrumental and has not touched the philosophical or ethical dimensions of the technology itself. Therefore, it is important to integrate the use of science and technology in science learning with a philosophy of science approach, so that students are not only proficient in using technology, but also able to reflect on the social, environmental and value impacts of the technology. Thus, a pedagogical approach is needed that not only combines science and technology technically, but also through learning models that prioritize reflection and ethics.

3. Reflective and Ethical Learning Models in the Context of Science

Learning approaches that combine philosophy of science and science and technology are widely developed in the form of learning models based on socio-scientific issues (SSI), reflective inquiry learning, and scientific ethics-based learning. The study by Nurhalimah et al. (2024) showed that SSI-based science learning can improve students' critical thinking, moral decision-making, and environmental awareness. In addition, science learning that includes discussions about ethics in experiments, the responsibility of scientists, and technological justice is considered more effective in forming students who have *scientific reasoning* as well as *scientific conscience* (Sundari et al., 2024).

4. Relevance to Current Science Education

The integration between philosophy of science and science and technology in science learning not only improves cognitive outcomes, but also supports the goals of character education, science literacy, and 21st century competencies. The literature review shows that this reflective-critical learning model is relevant to the implementation of the Merdeka Curriculum which emphasizes the profile of Pancasila learners, especially in the dimensions of critical reasoning, faith and piety in God, and global competence (Kemendikbudristek, 2022). Thus, science learning designed based on this integration is expected to be able to form students who not only understand science conceptually, but are also able to think rationally, consider values, and be responsible for the impact of the application of science and technology in life, so that it can be an alternative approach in implementing the Merdeka Curriculum substantively, not just administratively.

CONCLUSION

The integration of philosophy of science and science and technology in learning science is a strategic and relevant approach in responding to the challenges of 21st century education. This study shows that philosophy of science, through an understanding of epistemology, scientific logic, and ethical reflection, is able to strengthen the critical thinking dimension and scientific character of students. Meanwhile, science and technology, if used contextually and reflectively, not only function as learning media, but also as teaching materials that can foster ethical and social awareness of science. The results of the literature study confirm that science learning that combines philosophical approaches and technology utilization can improve science literacy, value awareness, and higher order thinking skills. Learning models such as Socio-Scientific Issues (SSI), reflective inquiry, and scientific ethics-based learning are effective alternatives in realizing critical, reflective, and civilized science education. This approach is also in line with the policy direction of the Merdeka Curriculum, which emphasizes the importance of strengthening character and holistic competence through contextual learning.

Based on the findings of this study, it is recommended that:

1. The development of science curriculum and teaching tools at the school level needs to explicitly integrate the dimensions of philosophy of science and ethical reflection in the utilization of science and technology.
2. Science teacher training should include strengthening philosophical insights, reflective pedagogy, and the use of technology with educational and ethical values.
3. Further research is recommended to explore the real implementation of learning models that combine philosophy of science and science and technology at various levels of education, in order to obtain empirical data on their effectiveness and applicative challenges.
4. The government and education policy makers need to encourage policies that support the creation of a critical, reflective, and contextual science learning ecosystem, both through regulation, mentoring, and strengthening digital literacy and scientific values among students.

Thus, the transformation of science learning based on the philosophy of science and science and technology not only allows students to become masters of science, but also become people who think critically, reason ethically, and act responsibly in the face of global dynamics.

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