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Systematic Literature Review: The Effectiveness of the History of Science Approach in Improving Conceptual Understanding in Physics Education

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Abstract: *This study aims to analyze the effectiveness of the History of Science (HoS) approach in improving students' conceptual understanding in physics learning through the Systematic Literature Review (SLR) method using the PRISMA model. A total of six articles selected from 779 initial findings that met the inclusion and exclusion criteria were analyzed in depth. The synthesis results show that the HoS approach can strengthen conceptual understanding. The History of Science has been proven to help students overcome misconceptions, improve scientific reasoning skills, and enrich epistemological understanding of the nature of science. However, the SLR findings also confirm that empirical research on the implementation of HoS in the classroom is still limited, requiring the development of more structured learning strategies and improved teacher competencies to optimize the application of this approach in physics learning. Overall, this study confirms that HoS has great potential in supporting more meaningful, contextual, and conceptually oriented physics learning.*

Keywords: *conceptual understanding, history of science, learning approaches, physics education, systematic literature review*

Tinjauan Pustaka Sistematis: Efektivitas Pendekatan Sejarah Ilmu Pengetahuan Untuk Meningkatkan Pemahaman Konseptual Dalam Pendidikan Fisika

Abstrak: Penelitian ini bertujuan untuk menganalisis efektivitas pendekatan History of Science (HoS) dalam meningkatkan pemahaman konseptual peserta didik pada pembelajaran fisika melalui metode Systematic Literature Review (SLR) dengan model PRISMA. Sebanyak enam artikel terpilih dari 779 temuan awal yang memenuhi kriteria inklusi dan eksklusi dianalisis secara mendalam. Hasil sintesis menunjukkan bahwa pendekatan HoS mampu memperkuat pemahaman konsep *History of Science* terbukti membantu siswa mengatasi miskonsepsi, meningkatkan kemampuan penalaran ilmiah, serta memperkaya pemahaman epistemologis terhadap hakikat sains. Walaupun demikian, temuan SLR juga menegaskan bahwa penelitian empiris mengenai implementasi HoS di kelas masih terbatas, sehingga dibutuhkan pengembangan strategi pembelajaran yang lebih terstruktur dan peningkatan kompetensi guru untuk mengoptimalkan penerapan pendekatan ini dalam pembelajaran fisika. Secara keseluruhan, studi ini menegaskan bahwa HoS memiliki potensi besar dalam mendukung pembelajaran fisika yang lebih bermakna, kontekstual, dan berorientasi pada pemahaman konseptual.

Kata Kunci: *history of science, pemahaman konseptual, pendekatan pembelajaran pendidikan fisika, tinjauan literatur sistematis*

INTRODUCTION

Science education aims to help students not only master facts and formulas, but also build a complete and meaningful conceptual understanding of natural phenomena (McDermott & Redish, 1999; Hasanah et al., 2021; Paramitha & Mustari, 2023; Safitri, 2023). Often, students still experience difficulties in developing a complete understanding of physics concepts, requiring a learning approach that emphasizes strengthening conceptual understanding (Pratiwi et al., 2024). Conceptual understanding is central to science learning because it enables students to understand the structure of concepts, the relationships between concepts, and the scientific thinking processes underlying the theories they learn, rather than simply memorizing information (Chakravartty, 2023; Nersessian, 1989; Qadar et al., 2025). To improve the quality of learning, an approach is needed that not only emphasizes content, but also pays attention to how science develops as a scientific discipline (Mody, 2025). In addition, understanding the characteristics of science, including its historical and epistemic dimensions, plays an important role in shaping students' conceptual understanding (Cheung & Erduran, 2023).

In the context of physics education, the history of scientific theory development offers opportunities to explore how classical to modern concepts were formed, tested, and revised (Zuccarini, Sutirni, et al., 2024). The historical transition between classical and quantum physics can help students build more coherent conceptual models, as the history of science provides an overview of how scientists in the past overcame conceptual conflicts (Zuccarini & Malgieri, 2024). These findings reinforce the position that the History of Science (HoS) approach can serve as a bridge between abstract concepts and students' gradually developing understanding.

Philosophically, the historical approach in science education has a strong theoretical foundation. Thomas Kuhn's view of scientific revolutions is relevant to modern science education, particularly in explaining how paradigm shifts influence how scientific concepts are understood and taught (Matthews, 2024). Kuhn's perspective suggests that the history of scientific development can be a pedagogical strategy for helping students understand that scientific concepts are dynamic and evolve through problem solving, debate, and theory reconstruction. On the other hand, the successful application of the history of science approach also depends on the teacher's epistemological understanding. Teachers who have a strong understanding of how science works as a discipline are better able to design learning that effectively integrates historical and epistemic aspects (Soysal, 2025). This emphasizes the importance of teacher readiness as a supporting factor that determines the successful application of the HoS approach in science concept learning.

Tracing the history of scientific theories provides an opportunity to show how classical and modern concepts were formed through experimentation, debate, and theoretical revision, thereby providing a contextual narrative that enriches the meaning of concepts for students. Furthermore, studies that model conceptual change in the transition between classical and quantum physics show that teaching the historical sequence of ideas along with the conceptual conflicts that arose at that time can help students build more coherent and integrated mental models (Brod, 2021). This approach facilitates understanding of how scientists resolve conceptual problems (e.g., paradigm shifts or the emergence of new concepts), enabling students to see the reasons behind theoretical changes rather than simply accepting new concepts as isolated facts (Nyirahabimana et al., 2024). In addition, integrating historical context into physics

learning also has the potential to increase motivation and relevance because students can relate abstract concepts to real developments in scientific practice.

Improving the quality of science education requires an approach that emphasizes not only mastery of content, but also an understanding of how science has developed as a scientific discipline. The HoS approach is important because it helps students see science as a dynamic process that has been built through argumentation, concept revision, and problem solving over time. However, in practice, much science learning is still procedural, teacher-centered, and does not provide enough space for students to explore the scientific thinking process in depth (Abd-El-Khalick & Lederman, 2000; Höttecke & Silva, 2011). Therefore, this research is important to identify how the use of historical ideas can improve the quality of scientific dialogue in the classroom and strengthen students' conceptual understanding more deeply.

METHOD

This study uses the Systematic Literature Review (SLR) method with the PRISMA design approach as the main framework. This method was chosen because it is able to answer specific research questions through systematic stages ranging from identification, screening, selection, quality evaluation, to synthesis of relevant literature (Pantic & Hamilton, 2024; Shaffril et al., 2021; Triandini et al., 2019). Each stage was designed to ensure that the articles analyzed were truly relevant to the main issue, namely the use of the HoS in science learning and its role in conceptual understanding. In the data collection stage, articles were searched through the Scopus and ERIC databases as the main sources because they cover internationally reputable publications in the fields of science education, science epistemology, and the history of science. The search process was conducted using several keywords, including: “History of Science in education,” “conceptual understanding,” and “historical approach science learning.” The initial search results produced a number of relevant articles which were then categorized based on topic relevance and data completeness.

Table 1. Inclusion and Exclusion Criteria

Category	Description
Inclusion criteria	<ol style="list-style-type: none"> 1. Articles published between 2010 and 2025. 2. Written in English. 3. Examine the integration of science history or epistemological aspects in learning. 4. Provides full text access.
Exclusion criteria	<ol style="list-style-type: none"> 1. Articles not relevant to the context of science education. 2. Non-scientific publications or editorials. 3. Articles without clear methodology.
Screening results	A number of articles that meet all criteria are selected for further analysis.

Articles that passed the selection process were then re-examined to ensure consistency in methodology, validity of content, and relevance to the research focus. Data analysis was conducted using a narrative approach to describe the characteristics of each study, such as educational level, research design, type of historical intervention, and findings related to conceptual understanding and scientific characteristics. Through this process, information from each article was synthesized to identify patterns of findings, research gaps, and potential contributions to the development of science history-based learning models.

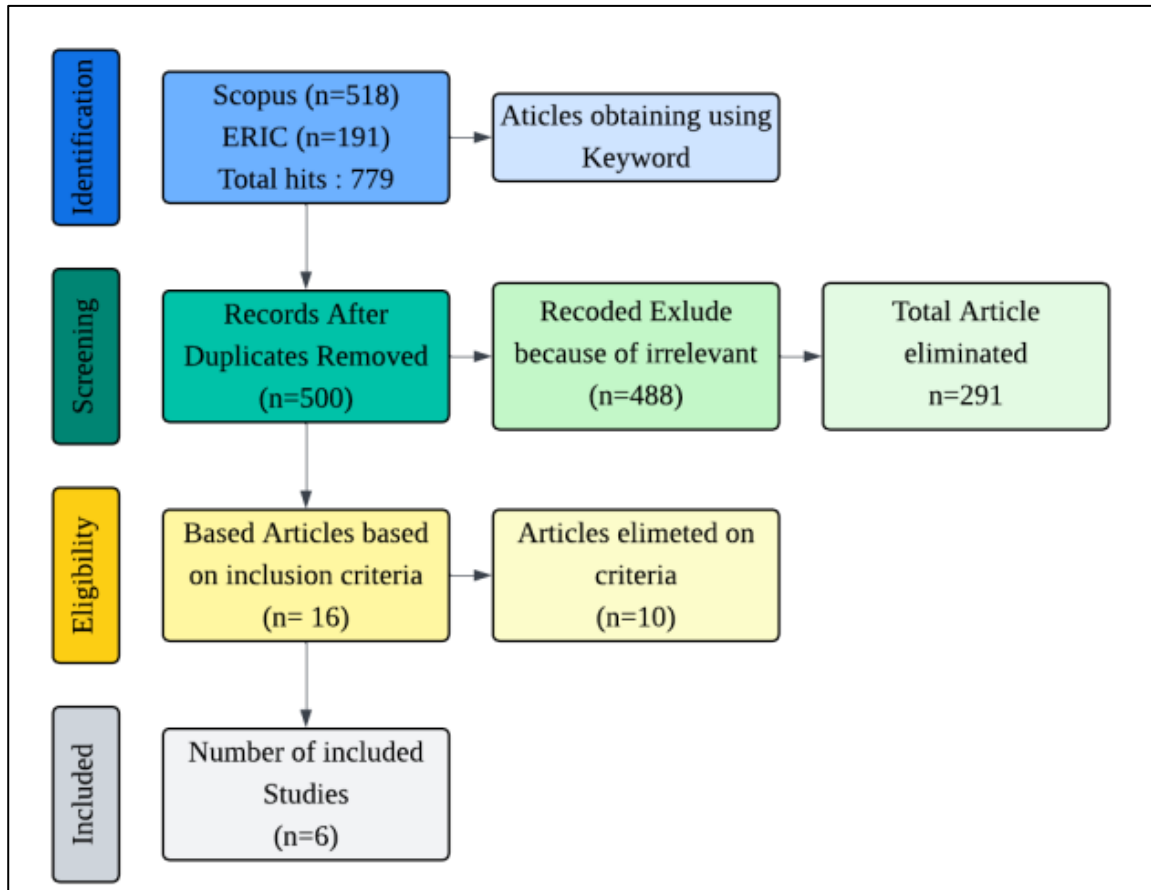


Figure 1. PRISMA Flow Diagram

In the data search stage, articles were identified from the Scopus and ERIC databases using predetermined keywords. The initial search yielded 779 articles. The screening stage was carried out by removing duplicates and checking the relevance of the titles and abstracts, leaving 500 articles. Based on the predetermined inclusion and exclusion criteria, the number of articles eligible for analysis was reduced to 16 articles. After a more in-depth methodological assessment, only 6 articles were selected for further analysis. The selected articles were then analyzed using a narrative approach to map research trends, methodological characteristics, and key findings in each study.

RESULTS AND DISCUSSION

Based on the process of identifying, screening, and selecting articles using the PRISMA flow, six articles were obtained. All articles met the inclusion and exclusion criteria that had been set. These articles were selected because they explicitly examined the application of the HoS approach in the context of physics and science learning. In addition, these articles also assessed its impact on students' conceptual understanding.

Table 2. Articles that Meet the Inclusion Criteria

Author	Variable	Topic	Method	Results / Findings
Paolo Bussotti (2024)	Conceptual understanding	Energy concept	Non-experimental	HoS approach can enhance understanding of energy, work, and heat without complex mathematics.

Author	Variable	Topic	Method	Results / Findings
Bächtold & Munier (2024)	Conceptual understanding	Energy concept	Mixed Method	HoS-based strategies improve students' understanding of energy.
Becker, Heidemann & Lima (2024)	Objectives, methods, and results of HoS research	Review of the use of science history in physics education	Non-experimental	HoS research is still largely theoretical; qualitative methods dominate; classroom implementation is limited.
Beauchemin & Staley (2024)	Conceptual understanding	Helmholtz and energy concept	Historical-qualitative study	HoS approach can improve students' conceptual understanding.
Igal Galili (2024)	Conceptual understanding	Weight concept	Historical-qualitative study	HoS use improves students' conceptual understanding of weight.
Yafeng Zheng et al. (2024)	Conceptual & epistemological understanding	Scientific inquiry concepts	Quasi-experimental study	Use of the HoS in learning can utilize both types of feedback to strengthen conceptual understanding and epistemological understanding of students.

Based on the findings in Table 1, the studies included in the systematic literature review (SLR) and relevant empirical articles provide a comprehensive overview of the effectiveness of the History of Science (HoS) approach in improving students' understanding of physics concepts. From the collection of articles analyzed, it appears that the integration of science history in physics learning not only has a positive impact on conceptual understanding but also improves students' ability to interpret scientific processes more deeply, including the development of epistemological reasoning and scientific argumentation skills.

According to research conducted by Becker et al., (2024) studies related to the application of HoS in physics education have grown significantly over the past decade. Of the 1,296 articles screened, only 32 studies met the criteria for empirical research, and most of them used a qualitative approach. These findings indicate that although HoS is considered to have the potential to help students understand physics concepts, its direct implementation in the classroom is still limited. The SLR results confirm that the use of science history contributes significantly to improving conceptual understanding, understanding the nature of science, and interest in learning physics.

The study by Bächtold & Munier, (2019) provides empirical evidence supporting the findings of the SLR. Using the History and Philosophy of Science (HPS) approach, this study shows that learning energy concepts involving the reproduction of Joule's experiments, reading scientific historical texts, and introducing energy concepts from a historical perspective can significantly improve students' understanding. Results Pre-tests and post-tests showed a clear improvement in understanding energy transformation and the principle of energy conservation, and helped students eliminate common misconceptions, such as the substantial view of energy.

Bussotti (2023) reinforces these findings through a historical analysis of the concept of energy as explained in Hermann Helmholtz's popular lectures. This article shows that a historical approach can organize abstract concepts such as energy, work, heat, and

entropy. By placing the development of energy concepts in the context of the industrial revolution, students can understand the ontological and epistemological reasons underlying the emergence of these concepts. This confirms that the integration of science history not only aids conceptual understanding but also provides a social, philosophical, and cultural context that enriches learning.

The study Beauchemin & Staley, (2024) makes an important philosophical contribution to the effectiveness of the HoS approach. Through a pragmatic model of exploratory experimentation, this study shows that scientific concept understanding comes not only from theory, but also from investigative practice in its historical context. These findings are relevant to HoS-based learning, as they confirm that students can gain a more meaningful understanding of concepts when exploring how earlier scientists developed knowledge through experimentation, challenges, and theoretical reflection.

In addition, research Zheng et al., (2024) adds a pedagogical perspective by comparing directive and reflective feedback in online science inquiry activities. The results show that using the HoS approach in combination with both types of feedback can strengthen students' conceptual and epistemological understanding. Reflective feedback improves students' understanding of the sources of knowledge, while directive feedback better supports argumentation skills. These findings indicate that HoS-based teaching strategies can be adapted to various forms of intervention to improve scientific learning.

CONCLUSION AND RECOMMENDATIONS

Overall, findings from SLR and supporting research indicate that the history of science approach is highly effective in improving students' conceptual understanding in physics. HoS helps students understand concepts not as ready-made facts, but as the result of a long process involving events, experiments, revisions, and scientific discoveries. This approach also strengthens higher-order thinking skills, fosters an appreciation for the nature of science, and helps reduce misconceptions that often arise in physics learning. However, empirical research related to the implementation of HoS still needs to be developed, especially in real classroom learning. The limitations of experimental research indicate the need for further exploration to prove the effectiveness of the HoS strategy in various contexts and physics topics. Thus, although HoS has been proven effective in theory and concept, systematic implementation based on empirical evidence remains a great opportunity for future physics education research.

Future research needs to conduct more empirical and classroom-based studies to provide stronger evidence of the effectiveness of the HoS approach. Teachers should receive training to integrate historical perspectives into physics instruction, and curriculum developers are encouraged to include historical contexts to support students' conceptual understanding.

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