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Research Article

Critical Thinking Skill and Cognitive Learning Outcomes in Learning Physics: A Literature Review

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Abstract.

Physics education helps students develop critical thinking skills essential for understanding natural phenomena and solving everyday problems. However, the relationship between critical thinking skills and cognitive learning outcomes in physics education is complex and requires a comprehensive literature review. This article explores this relationship and analyzes effective teaching strategies using a literature review method and collecting secondary data from sources such as national and international journals. The results show that innovative learning models, such as project-based and blended learning, significantly enhance students' critical thinking skills and cognitive learning outcomes in physics. Additionally, integrating technology has been proven to increase the engagement and effectiveness of learning. Fostering an active, collaborative learning environment supported by technology is crucial for developing students' critical thinking abilities and preparing them to face future challenges.

Keywords: cognitive learning outcomes, critical thinking skill, physics

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1. INTRODUCTION

Physics education is a fundamental aspect of education that explores natural phenomena and occurrences through scientific processes (1,2). Through physics education, students can develop various skills, including critical, logical, analytical, systematic thinking, honesty, and discipline. These skills are crucial for solving physics concepts related to everyday life (2).

In 1956, Benjamin Bloom and his colleagues developed Bloom's Taxonomy, which classifies educational objectives into three main domains: cognitive, psychomotor, and affective (3). The cognitive domain encompasses hierarchical thinking skills, ranging from simple recall of information to complex research (4). Learning outcomes reflect the knowledge, understanding, and application students achieve after the learning

process, which can be categorised into cognitive, affective, and psychomotor domains (5). Cognitive learning outcomes refer to academic achievements measured through standardised tests, closely linked with intellectual skills interconnected with affective and psychomotor abilities (6).

One of the internal factors influencing learning outcomes is students' critical thinking abilities. Critical thinking is an essential skill in the 21st century, involving a combination of complex cognitive skills used for directed thinking (7). This active and structured thought process allows students to understand themselves better and enhances their awareness of events around them through reflection and application of thinking processes (8). Developing critical thinking skills in physics education is vital, as it helps students comprehend complex concepts, solve problems, and apply their knowledge in real-world situations.

The importance of critical thinking in education is widely recognised. Numerous studies have shown that critical thinking skills assist students in analysing and interpreting data, formulating hypotheses, and developing logical arguments, supporting their academic success and preparing them for future challenges (9). Facione (2015) explains that critical thinking skills are based on six leading indicators: interpretation, analysis, inference, evaluation, explanation, and self-regulation (10).

Given the complexity of the relationship between critical thinking skills and cognitive learning outcomes, a comprehensive literature review is necessary. This review explores the relationship between critical thinking skills and cognitive learning outcomes in physics education. By examining various studies and research articles, this review will provide insights into how critical thinking skills can enhance students' cognitive abilities and improve their learning experiences in physics. Additionally, it will analyse the teaching strategies and interventions implemented to improve critical thinking skills in physics classes. By synthesizing findings from these studies, it is hoped to understand how critical thinking can be effectively integrated into physics education to enhance students' cognitive learning outcomes.

2. METHOD

2.1. Type of Research

This research adopts the literature review method. A literature review is a methodological tool used to answer research questions, evaluate theories or evidence, examine the

validity or accuracy of specific theories, and provide an overview of a particular issue or research problem (11) . It also refers to a data collection technique that analyses books or literature related to the problem to generate information used as the outcome of the library research.

2.2. Research Procedures

According to Kuhlthau (12), the literature review procedure involves several crucial steps: selecting a topic, seeking information, determining the research focus, gathering data sources, preparing data presentation, and finally, compiling the report. These steps provide a structured framework for composing a comprehensive literature review. Here is a diagram outlining the literature review procedure:

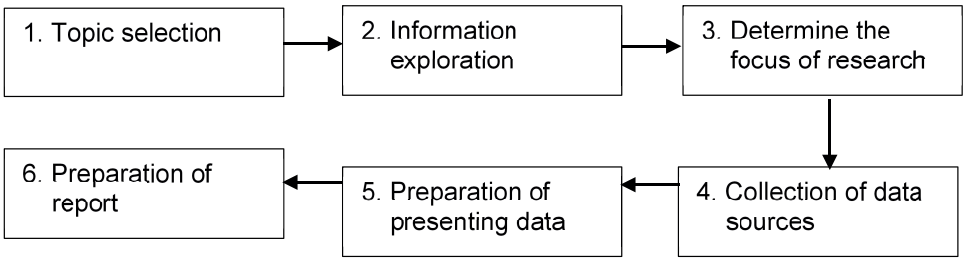

Figure 1: diagram outlining the literature review procedure.

2.3. Data Collection Techniques

In literature research, data collection techniques involve the use of secondary data. Secondary data is collected by others, not by the researcher, and is usually gathered for purposes different from the current research (13). In secondary research, researchers can utilise data from various sources, such as government documents, scientific articles, and statistical databases. Researchers can leverage previously collected information using secondary data, and relevant policy variables can be easily derived from these data sources (14). The secondary data in this research comprises documents examining the variables and subjects studied from national and international journals related to critical thinking and cognitive learning outcomes in physics education, as well as sources from web pages that are analysed and presented concisely and clearly.

2.4. Data Analysis Techniques

This study employs a qualitative approach with descriptive data analysis to delve deeply into the collected literature. The analysis process includes collecting data from various sources, transcribing it into text, and conducting an in-depth examination of each part of the data. The data is then grouped based on themes, patterns are identified and interpreted within the context of relevant theories. After thorough analysis, conclusions are drawn.

3. RESULTS AND DISCUSSIONS

Based on the collected secondary data, several articles are relevant to critical thinking skills and cognitive learning outcomes in physics education. Each article will be analysed, followed by the next one. The data obtained is recorded in Table 1.

TABLE 1: Analyze several articles relevant to critical thinking skills and cognitive learning outcomes in physics education.

Title and Researchers	Objective	Result
Implementation of Guided Inquiry Learning Model to Improve Understanding Physics Concepts and Critical Thinking Skill of Vocational High School Students(15)	This research aims to implement the guided inquiry learning model to improve the understanding of concepts and critical thinking skills of Vocational High School (SMK) students	The results show an average increase in the experimental class's understanding of physics concepts and critical thinking skills by 0,71 (high category) and the control class by 0,28 (low category). Implementing guided inquiry learning models significantly improves the understanding of static fluid concepts and critical thinking skills of Vocational High School students compared to conventional learning.
Merry Go Round Technique And Students' Physics Cognitive Learning Outcomes On Work And Energy Topic(16)	This study aims to determine the difference in physics learning outcomes on the topic of work and energy between students who learned using the inquiry training model with merry-go-round techniques and those who learned conventionally	The results show that the experimental class had the highest average score of 85,27 compared to the control class with an average score of 77,564. The hypothesis test results indicate significant differences in physics learning outcomes between students who studied using the inquiry training model with merry-go-round techniques and those who studied conventionally.
The Effectiveness of Inquiry Learning Models Intervened by Reflective Processes to Promote Critical Thinking Ability in Terms of Cognitive Style(17)	This study aims to explore the effectiveness of inquiry learning models intervened by the reflective process to promote the critical thinking ability of preservice teachers in terms of cognitive style	The study results show that the inquiry learning model intervened by the reflective process effectively promotes the critical thinking ability of preservice teachers with FD and FI cognitive styles45. The average pretest score was 0,87 with the criteria of "less critically." After the implementation of the learning model, the average posttest score was 16,25 with the criteria of "critically" and an n-gain of 0,64 with the criteria of "moderate."

Table 1: Continued.

Title and Researchers	Objective	Result
Quantum Flipped Learning and Students' Cognitive Engagement in Achieving Their Critical and Creative Thinking in Learning(18)	To analyze the main and interactive effects between the Quantum Flipped Learning (QFL) model and the Direct Flipped Learning (DFL) model, as well as students' cognitive engagement on their critical and creative thinking in learning physics	The study found that students who studied with the Quantum Flipped Learning (QFL) model exhibited significantly higher critical and creative thinking skills compared to those who studied with the Direct Flipped Learning (DFL) model1. Additionally, students with high cognitive engagement demonstrated critical and creative thinking skills similar to those with low cognitive engagement. Importantly, there was no interactive effect between the learning model and students' cognitive engagement on their critical and creative thinking skills
Improving Critical Thinking Skills In Physics Learning Through Project Based Learning(19)	The purpose of this research is to determine whether there is an enhancement in students' critical thinking skills using the Project Based Learning (PjBL) mode	The results showed that students' critical thinking skills improved when the Project Based Learning model was applied compared to learning that did not use the model
The influence of scientific creativity and critical worksheets (SCCW) on creative thinking skills and critical scientific as well as students' cognitive abilities on project-based learning work and energy concepts(20)	The aim of this study was to find out the improvement of cognitive ability, creative thinking skill, and critical scientific thinking skills of students by applying a project-based learning model integrated with Scientific Creativity and Critical Worksheets (SCCW) and Conventional Student Worksheets (CSW)	The results of the study indicate that the implementation of SCCW in project-based learning can improve creative thinking skills, critical scientific thinking skills, and cognitive abilities of students with greater improvement than the application of CSW in project-based learning.
Development of Physics Students Worksheets with Scientific Approaches to Improve Skills Critical Thinking and High School Student Learning Outcomes(21)	This study aims to produce student worksheet products with a scientific approach that are suitable for enhancing critical thinking skills and high school student learning outcomes. It seeks to determine the improvement in students' critical thinking skills after employing these worksheets in the physics learning process and to identify the resulting increase in student learning outcomes post-implementation.	Developed student worksheets utilizing a scientific approach were found suitable for Class X high school learning on temperature and heat topics, receiving very good ratings from material validators, good from media validators, and very good from language validators. Students' critical thinking skills showed a moderate improvement, with a gain value of 0,67 from pretest to posttest results. Additionally, cognitive learning outcomes demonstrated a high improvement, indicated by a gain value of 0,73.

Table 1: Continued.

Title and Researchers	Objective	Result
The Role of Cognitive Conflict Approach to Improving Critical Thinking Skills and Conceptual Understanding in Mechanical Waves(22)	This study aims to determine the effect of the cognitive conflict approach on critical thinking skills and conceptual understanding in mechanical wave material.	The results of the study showed that there were differences in scores between the pretest and posttest on students' critical thinking skills and conceptual understanding in mechanical wave material in each experimental group. The cognitive conflict approach improved students' critical thinking skills and conceptual understanding
Enhancing Learning Outcomes: A Study on the Development of Higher Order Thinking Skills based Evaluation Instruments for Work and Energy in High School Physics(23)	This study aimed to enhance student learning outcomes in the field of work and energy within senior high schools through the development of evaluation instruments based on higher-order thinking skills (HOTS).	The outcomes demonstrated a significant improvement in student learning achievements concerning work and energy when using evaluation instruments founded on higher-order thinking. Students who utilized this instrument exhibited superior critical thinking skills, enhanced problem-solving abilities, and an improved capacity to apply physics concepts in real-life situations.
The Use Of Multimodal Representation In The Physics Learning Material Development To Promote Students' Cognitive And Critical Thinking Competences(24)	The research aimed to develop physics learning material by infusing multimodal representation to promote students' cognitive and critical thinking competences	The results showed that the physics learning material developed with multimodal representation was more effective in promoting students' cognitive and critical thinking competences than the physics textbook used in schools. The Cohen's d values for cognitive and critical thinking competences were 1,66 and 1,63, respectively, which are classified as high
Critical Thinking Skills and Physics Learning Outcomes in The 5E Learning Cycle Model with PhET Simulations(25)	To examine the significant effect of the 5E learning cycle model with PhET simulations on students' critical thinking skills and students' physics learning outcomes	There is a significant effect of the 5E learning cycle model with PhET simulations on students' critical thinking skills and students' physics learning outcomes
The YouTube-assisted discovery learning model: Improving students' cognitive learning outcomes and critical thinking(26)	The objective of this research is to determine the differences in student cognitive learning outcomes and critical thinking before and after applying the YouTube-assisted discovery learning model	The results showed significant differences in cognitive learning outcomes and critical thinking skills before and after applying the YouTube-assisted discovery learning model. There was an increase in cognitive test scores and critical thinking of students after applying the learning model.
The effect of blended learning setting on students' critical thinking skills in physics(27)	The purpose of this study was to examine the effectiveness of blended learning settings using Schoology in improving students' critical thinking skills and to explore students' responses about the learning approach	The results of the study revealed a significant difference in critical thinking skills between the experimental and control classes. The Schoology-based blended learning was effective in improving students' critical thinking skills. Additionally, students found the learning approach engaging, easy to follow, and beneficial for enhancing their knowledge. However, there were challenges related to internet connectivity.

Table 1: Continued.

Title and Researchers	Objective	Result
The Effect of Critical Thinking Skills and Achievement Motivation on Student Physics Learning Outcomes(28)	The objective of this research is to understand the overview of students' critical thinking skills, achievement motivation, and physics learning outcomes, and to analyze the direct and indirect effects of these variables.	The results indicate that students' critical thinking skills, achievement motivation, and physics learning outcomes are all in the high category. Critical thinking skills directly and significantly positively affect physics learning outcomes and achievement motivation. Achievement motivation also directly and significantly positively affects physics learning outcomes. Additionally, critical thinking skills indirectly affect physics learning outcomes through achievement motivation.

Articles discussing critical thinking skills and cognitive learning outcomes in physics students highlight various practical teaching approaches and models. One notable study is by Maknun (2020) (15) titled "Implementation of Guided Inquiry Learning Model to Improve Understanding Physics Concepts and Critical Thinking Skill of Vocational High School Students." This article explores implementing a guided inquiry learning model to enhance the understanding of physics concepts and critical thinking skills among vocational high school (SMK) students in Bandung, Indonesia. Using a quasi-experimental method, the study compares the outcomes of guided inquiry learning with conventional learning methods. The findings reveal that students in the experimental group, who experienced guided inquiry learning, showed significantly higher improvements in their understanding of physics concepts and critical thinking skills than the control group. The guided inquiry learning model enables students to construct knowledge actively through problem-solving, hypothesis formulation, data collection, analysis, and conclusion.

Additionally, in the study "Merry-Go-Round Technique And Students' Physics Cognitive Learning Outcomes On Work And Energy Topic" by Batlolona et al. (2021) (16), the inquiry training model was combined with the Merry-Go-Round (MGR) technique to investigate its impact on students' cognitive learning outcomes in physics, particularly on the topics of work and energy. In the MGR method, students are divided into small groups and rotate around different stations or tasks, each focusing on a specific aspect of the studied topic. This research, conducted on 74 tenth-grade students, found that the MGR technique's experimental group achieved significantly higher learning outcomes than the control group. These findings align with Verawati et al. (2020) (17), who demonstrated that an inquiry learning model, when supplemented with reflective processes, also enhances students' critical thinking skills, regardless of their cognitive

style. This comprehensive approach highlights the effectiveness of incorporating the MGR technique and reflective inquiry in improving students' cognitive learning outcomes and critical thinking abilities in physics.

On the other hand, Agustini et al. (2022) (18) introduced Quantum Flipped Learning (QFL), demonstrating its higher effectiveness compared to Direct Flipped Learning (DFL) in fostering critical and creative thinking skills in physics students. This study emphasises the importance of cognitive engagement, where students actively participating in learning tasks show better outcomes. Cognitive engagement refers to how students engage in learning tasks, including the effort invested and the thinking done during academic tasks (29,30). The research, involving high school students, utilised various tests and questionnaires to measure outcomes. The findings reveal that QFL is more effective in promoting critical and creative thinking, regardless of the student's level of cognitive engagement.

The article by Halmaida et al. (2020) (19) titled "Improving Critical Thinking Skills in Physics Learning Through Project-Based Learning" discusses the enhancement of students' critical thinking skills in physics education through the Project-Based Learning (PjBL) model. This study was conducted with 16 students from Class X MIA-1 at SMAN 2 Bukit. The results indicate that implementing PjBL significantly improves students' critical thinking skills compared to conventional teaching methods. PjBL engages students actively in learning, problem-solving, and developing critical thinking skills.

Similarly, Wulansari et al. (2019) (20) in their study titled "The Influence of Scientific Creativity and Critical Worksheets (SCCW) on Creative Thinking Skills and Critical Scientific Thinking, as well as Students' Cognitive Abilities on Project-Based Learning Work and Energy Concepts" investigated the impact of Scientific Creativity and Critical Worksheets (SCCW) on students' creative thinking, critical scientific thinking, and cognitive abilities within the framework of project-based learning. Conducted with high school students in Indonesia, this research compared the effectiveness of SCCW with conventional worksheets (CSW). Using a pre-experimental design with randomised control groups, pre-tests and post-tests measured cognitive and thinking skills improvements. The results demonstrated that SCCW significantly enhanced students' cognitive abilities, creative thinking, and critical scientific thinking compared to CSW. Like previous studies, the importance of Project-Based Learning (PjBL) is highlighted as a practical approach for improving students' critical thinking and cognitive skills by actively engaging them in the learning process through direct projects and using supporting tools such as worksheets.

In the same context, the study by Algiranto and Sulistiyono (2021) (21) highlights the importance of developing physics student worksheets (LKS) based on a scientific approach to enhance critical thinking skills and learning outcomes at the high school level. Conducted at SMA Muhammadiyah Imogiri, the research utilised the 4-D model (define, design, develop, disseminate) and found that these worksheets significantly improved students' critical thinking skills and cognitive learning outcomes. The study showed a notable increase in students' critical thinking skills, with a gain value of 0.67, and cognitive learning outcomes, with a gain value of 0.73. Through the right approach, as implemented in these worksheets, students are given opportunities to think critically and engage more deeply in the learning process.

Moreover, innovative approaches in physics education have also shown significant potential in enhancing critical thinking skills and learning outcomes. Makhrus and Hidayatullah's (2021) (22) study adopted a cognitive conflict approach to encourage students to confront and resolve contradictions between their initial understanding and new information. This research explored the impact of the cognitive conflict approach on improving critical thinking skills and conceptual understanding of mechanical waves among 11th and 12th-grade students. Conducted as a pre-experimental study with a one-group pretest-posttest design, it involved three experimental groups from a high school in Mataram. The findings indicated that the cognitive conflict approach significantly improved students' critical thinking and conceptual understanding, evidenced by higher posttest scores than pretest scores. The study concluded that this approach effectively bridged students' initial concepts with new learning, fostering better understanding and critical thinking.

Moreover, the Higher-Order Thinking Skills (HOTS) approach has great potential to enhance physics learning outcomes. In the study titled "Enhancing Learning Outcomes: A Study on the Development of Higher-Order Thinking Skills based Evaluation Instruments for Work and Energy in High School Physics" by Kusumaningtyas et al. (2023) (23) the development of HOTS-based evaluation instruments to improve high school physics learning outcomes, particularly on the topic of work and energy, is discussed. This research emphasises the importance of HOTS, which includes analysis, evaluation, and creative problem-solving, in enhancing students' critical thinking and problem-solving skills. The study followed a development approach involving needs analysis, instrument design, validation, and implementation. The results showed a significant increase in students' academic performance and critical thinking skills when using HOTS-based evaluation instruments. This study underscores the importance of HOTS in education,

which goes beyond basic understanding to include analysis, evaluation, and creation. These skills are crucial for solving complex problems and applying knowledge in real-world scenarios.

Additionally, the study by Nussifera et al. (2017) (24) highlights the effectiveness of using multimodal representations in developing physics learning materials to enhance students' cognitive abilities and critical thinking skills. This study emphasises using various modes (verbal, visual, graphic) in teaching materials to cater to different learning styles, thereby improving comprehension and engagement. The research conducted with 54 eleventh-grade students in Bandung found that these learning materials were more effective than traditional textbooks. Utilising a Research and Development method, the study showed a significant increase in students' cognitive and critical thinking competencies, with high Cohen's d values indicating solid effects. Cohen's d values for cognitive and critical thinking competencies were 1.66 and 1.63, respectively, classified as high.

Furthermore, the study by Purfiyansyah et al. (2023) (25) explores the impact of the 5E learning cycle model—comprising engagement, exploration, explanation, elaboration, and evaluation—combined with PhET simulations on students' critical thinking skills and physics learning outcomes. This study was conducted as pure experimental research with a post-test-only control group design involving eleventh-grade science students from SMA Negeri Balung. The research found significant improvements in critical thinking and physics learning outcomes for students taught using the 5E model with PhET simulations compared to traditional methods. PhET simulations were an interactive learning medium to help students grasp abstract physics concepts. These simulations make learning more engaging and effective by allowing students to explore and experiment virtually. This study highlights the effectiveness of integrating interactive simulations in enhancing educational outcomes and suggests that this approach can be a valuable tool in physics education.

In addition to the discussed learning models, the study by Akihary et al. (2023) (26) titled "The YouTube-assisted Discovery Learning Model: Improving Students' Cognitive Learning Outcomes and Critical Thinking" explores the impact of using YouTube as an aid in the Discovery learning model to enhance cognitive learning and critical thinking among students. After implementing the YouTube-assisted discovery learning model, the results indicated significant improvements in cognitive learning and critical thinking skills. Following this model, the study found substantial increases in students' cognitive test scores and critical thinking abilities. Integrating YouTube as a learning tool made the

material more accessible and engaging for students, leading to better understanding and retention.

Another study by Suana et al. (2020) (27) investigated the impact of blended learning environments on the critical thinking abilities of high school physics students. The research was conducted at a high school in Metro, Lampung, Indonesia, and utilised Schoology as a blended learning platform. Employing a quasi-experimental design with pre-tests and post-tests to measure critical thinking skills, it also included qualitative surveys to gather student feedback. The results showed significant improvements in critical thinking skills for students in the blended learning group compared to the control group. Students reported high interest and ease of learning with the blended learning model despite challenges related to internet connectivity. The study found that the blended learning approach significantly enhanced students' critical thinking skills in physics, highlighting the potential of integrating technology into education. Students expressed high-interest levels and found the blended learning model easy to use, indicating that this approach can boost student motivation and engagement.

"The Effect of Critical Thinking Skills and Achievement Motivation on Student Physics Learning Outcomes" by Syamsinar et al. (2023) (28) explores the relationship between critical thinking skills, achievement motivation, and physics learning outcomes among high school students. Conducted at SMA Negeri 2 Gowa, this study utilised a survey method with a sample of 80 students. The findings revealed that both critical thinking skills and achievement motivation significantly impact students' physics learning outcomes. Additionally, critical thinking skills contribute indirectly through achievement motivation, indicating that developing critical thinking enhances learning outcomes directly and motivates students to learn better. Overall, the findings from various studies highlight the importance of implementing innovative approaches in physics education to enhance critical thinking skills and students' learning outcomes.

The various studies demonstrate that implementing innovative learning models is crucial in enhancing students' critical thinking skills and cognitive learning outcomes in physics. From guided inquiry learning models and Merry-Go-Round techniques to project-based and blended learning approaches, each significantly improves students' understanding of physics concepts and critical thinking skills. Additionally, integrating technology, such as using PhET simulations and learning platforms like YouTube and Schoology, has proven to increase student engagement and motivation. These findings underscore that active, collaborative, and technology-based learning improves

academic performance and prepares students to face real-world challenges with strong critical thinking skills.

These studies highlight the importance of innovation in physics education and demonstrate that various creative and effective approaches can enhance critical thinking and cognitive skills. Educators can create more productive and beneficial learning environments by continuously developing and implementing learning strategies that support active student engagement, thus equipping students with the skills needed for future success.

4. CONCLUSION

This literature review highlights the crucial role of critical thinking skills in enhancing cognitive learning outcomes in physics education. Various innovative teaching models, such as guided inquiry, project-based, and blended learning, have significantly improved students' understanding of complex physics concepts and their critical thinking abilities. Integrating technology and interactive tools, like PhET simulations and YouTube-assisted learning, further boosts student engagement and learning effectiveness. Fostering an active, collaborative, and technology-supported learning environment is essential for developing students' critical thinking skills and preparing them to face real-world challenges.

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