IMPLEMENTATION OF STEM EDUCATION IN DEVELOPING CRITICAL THINKING SKILLS IN JUNIOR HIGH SCHOOL STUDENTS: SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

This study examines the implementation of STEM education in enhancing critical thinking skills among junior high school students. The main issue addressed is the low level of students' critical thinking ability. A Systematic Literature Review (SLR) following the PRISMA procedure was conducted, resulting in 13 relevant articles. The findings show that approaches such as PjBL-STEM, STEM-Design Thinking, flipped classroom, TPACK-STEM, and STEM-R effectively strengthen analysis, evidence evaluation, and problem-solving skills. STEM learning consistently improves students' critical thinking despite challenges such as limited facilities and teacher readiness. The study concludes that STEM education is an effective strategy for developing critical thinking skills in junior high school students.

Keywords: junior high school, stem, thinking skills

ABSTRAK

Penelitian ini mengkaji penerapan pendidikan STEM dalam meningkatkan keterampilan berpikir kritis peserta didik SMP. Permasalahan utama adalah rendahnya kemampuan berpikir kritis siswa. Penelitian ini menggunakan metode Systematic Literature Review (SLR) dengan alur PRISMA dan menghasilkan 13 artikel yang relevan. Hasil kajian menunjukkan bahwa model seperti PjBL-STEM, STEM-Design Thinking, flipped classroom, TPACK-STEM, dan STEM-R efektif dalam melatih analisis, evaluasi bukti, serta pemecahan masalah. Pembelajaran STEM terbukti meningkatkan kemampuan berpikir kritis secara konsisten meskipun terdapat kendala seperti fasilitas terbatas dan kesiapan guru. Penelitian ini menyimpulkan bahwa pendidikan STEM merupakan strategi yang tepat untuk mengembangkan keterampilan berpikir kritis peserta didik SMP.

Kata Kunci: Sekolah Menengah Pertama, STEM, Berpikir Kritis

A. Introduction

Education at the junior high school level is an important period for students to develop higher-order thinking skills. One of the key skills that needs to be developed is critical thinking, which is the ability to analyze information, evaluate arguments, and make logical and rational decisions. Critical thinking is fundamental to facing challenges in learning and everyday life, so school learning needs to be designed to support the development of this skill (Suandi et al., 2023).

One approach that is believed to support the development of critical thinking skills is STEM (Science, Technology, Engineering, and Mathematics) based learning. STEM education integrates four major disciplines to solve real-world problems through investigation, experimentation, and contextual application of concepts. Through STEM learning, students not only gain conceptual understanding, but are also trained to think logically, construct arguments, and solve problems using creative strategies (Irma et al., 2016)

STEM education is an approach to education in which science, technology, engineering, and mathematics are integrated into the educational process, focusing on solving real-life problems in everyday life and in professional life. As one of the key components of STEM, science focuses on examining natural phenomena through observation and measurement to objectively describe the constanly changing natural world. Technology encompasses human designed innovations developed to modify nature in order to satisfy human needs and preferences (Putra et al., 2021). Engineering involves the knowledge and skills required to obtain and apply scientific, economic, social, and practical principles to design and construct machines, tools, systems, materials, and processes that are economically advantageous and environmentally sustainable. Mathematics concerns the study of patterns and relationships and serves as a foundational language that supports technology, science, and engineering (Suwardi, 2021).

This study aims to provide a comprehensive overview of the implementation of STEM education in developing critical thinking skills among junior high school students. In

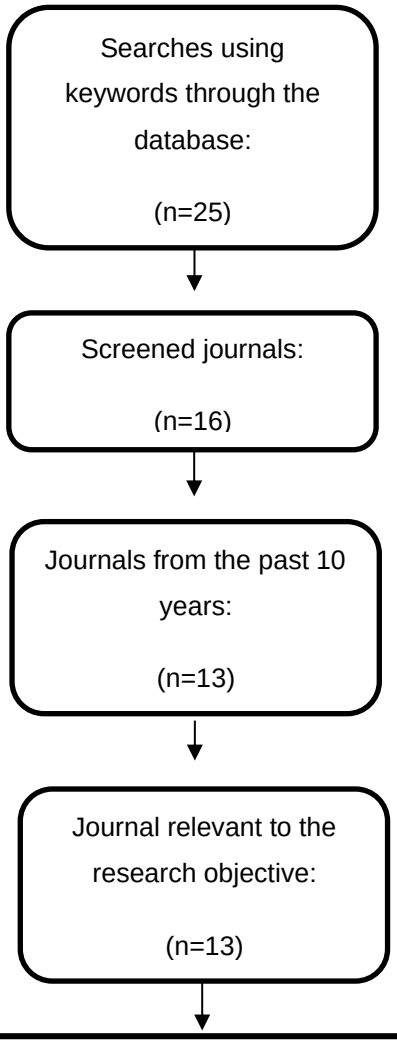
addition, the results of this study can also be used as a reference for educators, researchers, and policymakers in designing more effective learning strategies that are tailored to the needs of junior high school students. This study also opens up opportunities for further in-depth research related to the application of STEM in the context of learning at various levels of education.

B. Research Method

This study focuses on answering research questions formulated based on the objectives of SLR, namely examining the integration of STEM with the development of critical thinking skills in junior high school students. The research questions asked are as follows:

1. How does the implementation of STEM learning at the junior high school level support the development of critical thinking skills?
2. What are the main findings from previous studies on the relationship between STEM learning and critical thinking skills among junior high school students?

This study used the Systematic Literature Review (SLR) method following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow. PRISMA was chosen because it provides a systematic, transparent, and structured framework for conducting literature reviews so that the research results are more accountable. The PRISMA flow includes four main stages, namely identification, screening, eligibility, and inclusion.



Journals that were reviewed after elimination and were relevant to the research topic

(n=13)

C. Research Results and Discussion

RQ1 : How does the implementation of STEM learning at the junior high school level support the development of critical thinking skills?

Table 1 Implementation of STEM Learning at the Junior High School Level

No.	Author	Implementation of STEM Learning at the Junior High School Level
1	(Maruyama et al., 2022)	STEM learning is implemented through the UML (Unified Modeling Language) programming environment, which trains students to model systems using state machine diagrams. A case study was conducted at a Japanese junior high school on the topic of traffic light control.
2	(Sridana et al., 2025)	The application of STEM in the form of developing TPACK (Technological Pedagogical Content Knowledge)-based learning tools for junior high school mathematics teachers. The tools integrate digital technology (PowerPoint, video, and interactive worksheets) to train critical thinking through the exploration of functional concepts and problem solving.
3	(Anderson, 2012)	STEM learning is conducted through school-industry partnerships with real-world projects, such as designing sensors to detect tree diseases. Students are involved in the design process (design sprint) and think systematically to find technological solutions.
4	(Fayanto et al., 2023)	Analysis of junior high school science textbooks based on the integration of science, technology, and society.
5	(Wilis et al., 2023)	Application of STEM-based lesson plans in online science learning (topic: inheritance of living things)
6	(Retnowati et al., 2020)	Development of STEM-based mathematics modules for rectangular shapes in junior high school. Learning emphasizes problem solving, projects, and contextual experiments.
7	(’Ain et al., 2025)	Integration of STEM with Design Thinking (STEM-DT) through a water filtration project in junior high school.

8	(Salsabila et al., 2024)	Implementation of a simple STEM-based science project with an environmental theme (wastewater treatment using plants).
9	(Topano et al., 2023)	Development of STEM-based learning media in the form of charts (graphic sheets) on plant structure and function in junior high school. The application emphasizes the visualization of scientific concepts integrated with technology and simple engineering.
10	(Sarwi et al., 2024)	Implementation of the STEM-R (Science, Technology, Engineering, Mathematics, and Religion) approach in Islamic boarding school-based junior high schools. Learning integrates Islamic values and science-based project activities to enhance reflection and analysis.
11	(Suyono et al., 2025)	PjBL-STEM has been proven to improve creative and critical thinking skills through authentic and collaborative tasks. Research confirms the importance of integrating PjBL with STEM to strengthen higher-order thinking skills.
12	(Shofatun et al., 2024)	Development of a thematic project-based STEM learning design on “climate change” for eighth-grade junior high school students. Using the ADDIE model and worksheets based on thinking systems.
13	(Darmastuti et al., 2025)	STEM learning is implemented in the Flipped Classroom model, where students study the material independently before class activities. During learning, students integrate STEM through experiments and contextual discussions on Animalia biology material.

Based on thirteen journals, the application of STEM in junior high schools shows a consistent pattern, namely the integration of science, technology, engineering, and mathematics disciplines through real-world problem-solving activities. The most dominant approach is STEM-based Project-Based Learning (PjBL-STEM) because it provides space for students to design solutions, conduct experiments, and evaluate results reflectively. Several other studies apply STEM through programming, digital media, Design Thinking, and even the integration of religious values. This diversity of application demonstrates the flexibility of STEM to adapt to school characteristics and learning materials while remaining based on real-world problems and

investigative learning. However, several limitations have also been identified, such as teacher readiness, learning facilities, and variations in the quality of implementation.

RQ2 : What are the main findings from previous studies on the relationship between STEM learning and critical thinking skills in junior high school students?

Table 2 Key Findings on the Relationship Between STEM and Critical Thinking Skills

No.	Author	Key Findings on the Relationship Between STEM and Critical Thinking Skills
1	(Maruyama et al., 2022)	The use of UML programming helps students understand cause-and-effect relationships and think logically, which is the basis of critical thinking. Students are trained to analyze systems, predict outcomes, and refine models based on empirical evidence.
2	(Sridana et al., 2025)	The integration of TPACK-STEM contributes to improving students' critical thinking skills because it requires analysis, reflection, and application of mathematical concepts in real-world contexts. However, the level of implementation is still moderate, so teachers need further training.
3	(Anderson, 2012)	School-industry collaborative projects enhance critical thinking skills because students are confronted with authentic problems that do not have a single answer. They learn to evaluate evidence, analyze information, and develop innovative solutions.
4	(Fayanto et al., 2023)	It was found that science literacy (including critical thinking) was not yet optimal because the material was still dominated by knowledge aspects. The study emphasized the need to integrate the STEM approach so that students could develop scientific and critical thinking skills.
5	(Wilis et al., 2023)	STEM learning enhances higher-order thinking skills, including critical and creative thinking, through exploratory and reflective activities.
6	(Retnowati et al., 2020)	The STEM module significantly improves students' critical thinking skills (N-Gain 0.37, moderate category). Students are better able to analyze, evaluate, and relate concepts to real life.
7	(’Ain et al., 2025)	The STEM-DT model makes students more analytical and reflective in finding solutions, showing significant improvement in critical and creative thinking due to the stages of empathy,

		ideation, and prototype testing.
8	(Salsabila et al., 2024)	STEM project-based learning improves systemic thinking skills that are directly related to critical thinking. There was a 50% improvement in systemic analysis skills after learning.
9	(Topano et al., 2023)	STEM-based media has been proven effective in improving students' critical thinking skills. The practicality and effectiveness of the media reached >90%, indicating that students were better able to analyze and connect biological concepts to real-world contexts.
10	(Sarwi et al., 2024)	The integration of STEM with religious values significantly improves students' critical and reflective thinking skills. Students are better able to assess scientific phenomena using scientific approaches and religious ethics.
11	(Suyono et al., 2025)	A literature review shows that Project-Based Learning (PjBL) integrated with STEM is effectively implemented in junior high and high schools. Project-based learning activities encourage collaboration, independent research, and real-world problem solving.
12	(Shofatun et al., 2024)	STEM learning improves systematic and critical thinking skills regarding environmental issues. Students demonstrate improved ability to analyze cause and effect and logically design scientific solutions.
13	(Darmastuti et al., 2025)	This model significantly improves critical thinking skills ($p < 0.001$). Students are more active, analytical, and able to evaluate scientific information logically.

The results of the analysis show that all of the articles reviewed consistently state that STEM learning has a significant positive impact on the critical thinking skills of junior high school students. Improvements were seen in the ability to analyze information, evaluate evidence, understand cause-and-effect relationships, and make decisions based on data. Approaches that combine projects, scientific exploration, and digital technology have been shown to provide a deep learning experience that strengthens students' critical thinking skills. There were no conflicting findings, so it can be concluded that STEM is an effective approach that consistently improves critical thinking skills.

Overall, the results of the discussion of the two problem formulations show that the

implementation of STEM education at the junior high school level contributes strongly and consistently to the development of students' critical thinking skills. The application of STEM through various models—such as PjBL-STEM, STEM-Design Thinking, TPACK-STEM, flipped classroom, and STEM-R—has a similar pattern, which is to place students in real problem-solving situations that require analysis, evaluation of evidence, and logical reasoning. The findings in RQ1 and RQ2 also reinforce each other in that investigative activities, experiments, and contextual projects are key elements that can encourage significant improvements in critical thinking skills. Thus, it can be concluded that the integration of STEM in learning is not only relevant to the demands of a 21st-century skills-based curriculum but also effective in shaping scientific and reflective mindsets in junior high school students.

When examined comprehensively, the two research findings support each other: (1) STEM implementation models that place students as problem solvers, and (2) outcomes in the form of improved critical thinking skills through investigative, reflective, and project-based activities. Thus, it can be understood that the quality of critical thinking skills improvement does not depend on a particular model, but on the characteristics of STEM learning itself, namely the integration of science, technology, and solution design in a real-world context. Challenges such as limited facilities, teacher readiness, and curriculum adaptation are still encountered, but consistent findings show that when STEM is implemented with the support of learning tools and teacher guidance, positive effects on critical thinking skills still emerge significantly.

E. Kesimpulan

Based on an analysis of 13 relevant articles, it can be concluded that STEM-based learning consistently plays an important role in improving the critical thinking skills of junior high school students. Approaches such as PjBL-STEM, STEM-Design Thinking, STEM-based flipped classrooms, and TPACK-STEM integration enable students to analyze problems, evaluate evidence, and develop scientific solutions

logically. Despite obstacles such as limited facilities and teacher readiness, empirical evidence shows that STEM education is an effective strategy for developing higher-order thinking skills and supporting 21st-century learning. STEM implementation needs to be continuously strengthened through teacher training and the provision of adequate facilities to ensure optimal and sustainable learning.

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