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Building Students' Creative Thinking Skills in Science Learning : A Systematic Review of STEM-Based Approaches

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Abstract: This study aims to examines the effectiveness of the STEM approach in building students' creative thinking skills in science education, focusing on its implementation to meet students' needs in facing 21st-century challenges. This study employed a systematic literature review method adapted from PRISMA framework guidelines. Qualitative data collection techniques were employed, followed by thematic analysis for data interpretation. The literature analyzed was indexed in the Scopus and Google Scholar databases, with a publication range from 2022 to 2024. The study results found that using STEM effectively builds students' creative thinking skills in science learning. The STEM approach enhances students' comprehension of scientific ideas and motivates them to solve problems using critical and creative thinking. According to the results study, incorporating science, technology, engineering, and mathematics components into science instruction enables students to collaborate, innovate, and apply their knowledge in real-world contexts. Additionally, factors such as teacher support, resource availability, and a conducive learning environment are crucial in successfully implementing this approach. This study has implications for developing more effective curriculum and teaching strategies to enhance students' creative thinking skills. The long-term effects of the STEM method on students' academic performance and capacity for creative thought in many educational situations require more investigation.

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Introduction

Natural science is a field of study that teaches scientific facts and emphasizes the scientific process as a foundation for understanding natural phenomena (Muttaqin et al., 2022). In the learning of natural science, students are expected to interpret the material being taught and be able to solve problems in their environment related to the investigation of natural phenomena, which can also be interpreted as a process of discovery (Qomariyah & Subekti, 2021). Handayani et al. (2021) state that science learning should be able to instill scientific thinking through exploration, observation, and experimentation, so that students can understand the connection between theory and reality. However, in practice, Ristiani et al. (2025) explain that science learning in schools often focuses on memorizing content and outcome-based assessments, without providing meaningful opportunities for deep exploration. Science tends to appear theoretical and lacks contextual relevance, even though it has the potential to foster students' scientific reasoning and creativity. Therefore, in science learning, students must possess skills that support the learning process, have a strong conceptual understanding, and develop higher-order thinking skills (Hermansyah, 2020;

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Suharyat et al., 2022). Creative thinking is one of the higher-order cognitive abilities (Agustiawan & Irawati, 2022).

Creative thinking is the skills needed by an individual to think creatively in solving problems, encouraging students to explore new ideas, create innovative solutions, and adapt to change (Sari et al., 2024; Sirajudin et al., 2021; Suharyat et al., 2022). Behnamnia et al. (2025) state that creative thinking generates unique solutions and is a foundation for effective problem-solving processes in science learning. Creative thinking ability itself includes several important cognitive aspects. According to Guilford (1950) and Torrance (1965), there are four key factors: fluency, flexibility, originality, and elaboration. (Adhiriyanthi et al., 2021; Leasa et al., 2021). Puspita et al. (2024) explain how this skill empowers students to offer a range of different approaches to scientific issues and develop unusual yet relevant ideas. Thus, creative thinking ability is a key requirement in adaptive and meaningful science learning (Trisnayanti et al., 2020).

One approach considered capable of facilitating creative thinking skills is the Science, Technology, Engineering, and Mathematics (STEM) approach (Khalil et al., 2023; Lestari et al., 2018; Sumarni & Kadarwati, 2020). STEM emphasizes interdisciplinary learning oriented toward real-life situations and encourages students to use critical and innovative thinking when tackling difficult situations (Muttaqiin, 2023). Implementing STEM based on project-based learning can significantly improve high school students' creative thinking skills in science learning (Ilafi et al., 2024; Simatupang et al., 2024; Widyasmah et al., 2020). Science, Technology, Engineering, and Mathematics (STEM) can address real-world problems because their integrated nature positions students as problem solvers, inventors, and innovators, fostering independence, promoting logical thinking, and enhancing technological literacy (Agustina, 2023). Meanwhile, a study by Yang et al. (2025) states that implementing STEM in early childhood education can enhance both creative thinking skills and emotional development. This indicates that STEM is relevant at the secondary level and flexible for various educational stages. Therefore, integrating STEM into science learning is an auspicious approach to improving both the caliber of learning and students' creative thinking skills.

Several studies have highlighted the effectiveness of the STEM approach in fostering creative thinking skills (Ilafi et al., 2024; Khalil et al., 2023; Nazhifah et al., 2023; Pramesti et al., 2022; Safitri et al., 2024; Simatupang et al., 2024; Sukma et al., 2023; Tarihoran & Anas, 2023). This study aims to examines the effectiveness of the STEM approach in building students' creative thinking skills in science education, focusing on its implementation to meet students' needs in facing 21st-century challenges. The findings from this review are expected to offer valuable insights to help academics and educators create more creative and successful teaching methods that will improve students' capacity for creative thought.

Research Method

This study employs the Systematic Literature Review (SLR) method to explore the effectiveness of STEM in building creative thinking skills. SLR is chosen because it provides a comprehensive understanding of relevant research findings based on available secondary data (Chen et al., 2024). The review was conducted on articles published between 2022-2024, obtained from the Scopus and Google Scholar databases. The search keywords included "STEM" OR "STEM Approach" AND "Creative Thinking" AND "Science". All identified

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articles were selected using inclusion and exclusion criteria based on topic relevance and the availability of full-text access, as well as alignment with the research questions.

RQ 1 : What are the characteristics of the reviewed studies in terms of publication year, research topics, and subjects?
RQ 2 : What research methods were employed in these studies?
RQ 3 : What were the findings of these studies?

The process of data selection and analysis was conducted based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, which include the stages of identification, screening, eligibility assessment, and reporting. In the initial search phase, the researcher established specific criteria for including literature in the database, focusing only on journal articles that discuss the use of STEM to promote creative thinking skills in educational contexts. Inclusion and exclusion criteria were then applied, taking into account the publication period from 2022-2024 to ensure the relevance and timeliness of the data analyzed. Within the publish or perish tool, the search was carried out using the keywords "STEM" OR "STEM Approach" AND "Creative Thinking" AND "Science," with a specified limitation on the publication date range. This comprehensive search process yielded a total of 999 articles. To ensure the relevance and availability of the data, a set of specific criteria was applied to screen the articles. Table 1 displays the outcomes of the criteria used to the examined articles.

Table 1. Article Criteria

Type of Publication	Articles published in journals
Journal Spesification	International (Scopus) and National Jurnal Sinta 2
Year Published	2022-2024
Field	Sciences (Chemistry, Biology, Physics)
Language	English
Access	Open Access

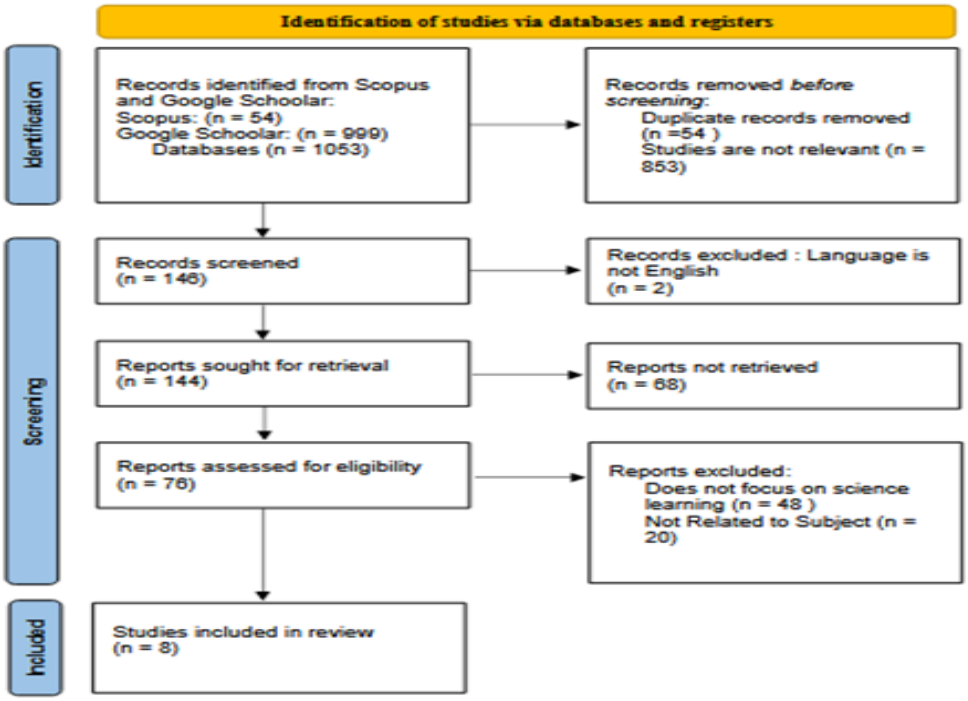

Figure 1. Prisma Flow Diagram

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After screening based on the inclusion criteria, 8 articles that satisfied the requirements and included a thorough overview of STEM and creative thinking in scientific education were found after carefully examining each item.

The number of journals identified through the Scopus database amounted to 54, while 999 journals were found in Google Scholar, making a total of 1.053 journals. From this total, 907 journals were removed, consisting of 54 duplicates and 853 that were considered irrelevant. Thus, the number of journals available for further screening was reduced to 146. After the screening process, 2 journals were excluded due to not being in English, leaving 144 journals to proceed to the next stage. Among these 144 journals, 68 were inaccessible for further review, reducing the number eligible for evaluation to 76. After a more in-depth analysis, 48 journals were removed because they were not aligned with the research's main focus, and 20 were excluded due to their irrelevancy to the subject of study. Consequently, only 8 journals remained that met all criteria and were suitable for further extensive analysis.

Results and Discussion

At the filtering stage by adjusting the inclusion and exclusion criteria of the identified journals, the researcher filtered and summarized 8 articles that met the criteria as in Table 2.

Table 2: Detail of Article

Index	Author (Year)	Title	Methods	Keywords
Sinta 2	Pramesti et al., 2022.	Effectiveness of project based learning low carbon STEM and discovery learning to improve creative thinking skills.	Experimental Research	PjBL-STEM; low carbon; creative thinking skills
Sinta 2	Nazhifah et al., 2023.	Development of STEM-Based E-Learning on Renewable Energy Topic to Improve the Students Creative Thinking Skills	Development Research	STEM; E-Learning; Creative Thinking
Sinta 2	Sukma et al., 2023.	Development of an E-Book Based on STEM-Integrated Creative Problem Solving on Environmental Change Material to Improve Students' Critical Thinking and Creative Thinking	Development Research	STEM; E-Book; creative problem solving; creative thinking; critical thinking
Q1	Khalil et al., 2023.	STEM-Based Curriculum and Creative Thinking in High School Students	Experimental Research	STEM-based curriculum; creative thinking; High School students
Sinta 2	Tarihoran & Anas, 2023.	Development of STEM-Based E-LKPD on Senses System Material to Improve Creative Thinking Ability	Development Research	Creative thinking;E-LKPD; STEM
Sinta 2	Simatupang et al., 2024.	STEM-PjBL: Its effect on students creative thinking skill in environmental pollution	Experimental Research	STEM-PjBL; Environmental Pollution;

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		material		Creative Thinking Skill
Sinta 2	Safitri et al., 2024.	The Influence of the STEM-Based Engineering Design Process Model on High School Students' Creative and Critical Thinking Abilities	Experimental Research	STEM; Creative Thinking Ability; Engineering Design Process
Sinta 2	Ilafi et al., 2024.	The Effect of Using e-Books with the STEM-PjBL Approach on Students' Learning Motivation and Creative Thinking Ability	Experimental Research	STEM approach; project based learning; learning motivation, creative thinking ability

RQ1. Research Topic and Subject

1.1 Research Topic

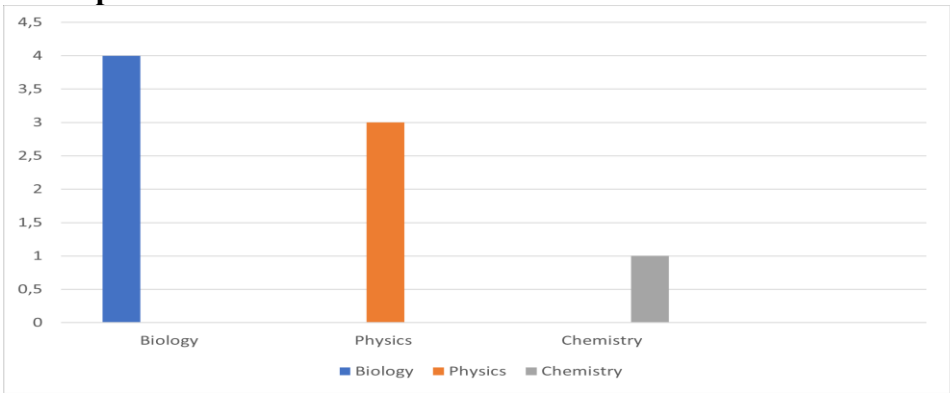

Figure 2. STEM Research Field Chart

Data about the research participants utilized in studies about creative thinking abilities and the STEM approach over the past three years. According to the figure, science is the most commonly studied discipline. It is suggested that science education should provide experience in addressing problems and emphasize the practical application of scientific concepts. Engaging students with real-world examples and challenges enhances their understanding in both theoretical and practical aspects. The STEM approach is the most effective method, encouraging students to apply creative thinking and problem-solving skills in real-life situations (Agustina, 2023)**.**

1.2 Research Subject

The study participants' responses served as the basis for the research findings. The studies primarily focused on two educational levels, with one of the key groups being junior high school and senior high school students. Eight articles with study subjects categorized for junior high school students were included (N = 3) (Ilafi et al., 2024); (Simatupang et al., 2024); (Pramesti et al., 2022). High school level (N = 5) (Khalil et al., 2023); (Sukma et al., 2023); (Nazhifah et al., 2023); (Tarihoran & Anas, 2023); (Safitri et al., 2024).

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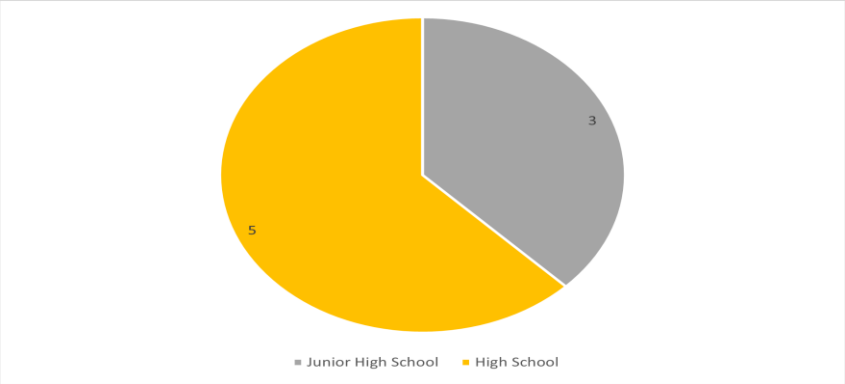

Figure 3. Graph of STEM Research Subject

Learning science in junior high school provides academic knowledge and equips students with skills and interests that will be highly valuable in their education and lives in senior high school and beyond (Yusnidar, Y., Fuldiaratman & Chaw, 2024). In science education, creative thinking skills are vital in producing original solutions and supporting effective problem-solving processes (Behnamnia et al., 2025). Implementing a STEM-based approach in science learning, which prioritizes the growth of innovative thinking, might offer junior and senior high school students key skills necessary to navigate academic and everyday challenges. Integrating Science, Technology, Engineering, and Mathematics (STEM) allows students to move beyond theoretical comprehension and toward applying concepts in innovative and creative problem-solving contexts (Muttaqiin, 2023). Such skills empower learners to develop novel ideas, respond to complex situations, and identify alternative solutions in both classroom and real-world scenarios (Puspita et al., 2024). Therefore, a STEM approach that nurtures creativity deepens scientific knowledge and contributes to students' personal growth and readiness for further education and future professional paths.

RQ2. Research Methods

The information in Figure 4 shows how researchers incorporated STEM and creative thinking techniques into their research. One of the two forms of study that were employed by (Pramesti et al., 2022); (Khalil et al., 2023); (Simatupang et al., 2024); (Safitri et al., 2024); (Ilafi et al., 2024). Development research used by (Nazhifah et al., 2023); (Sukma et al., 2023); (Tarihoran & Anas, 2023).

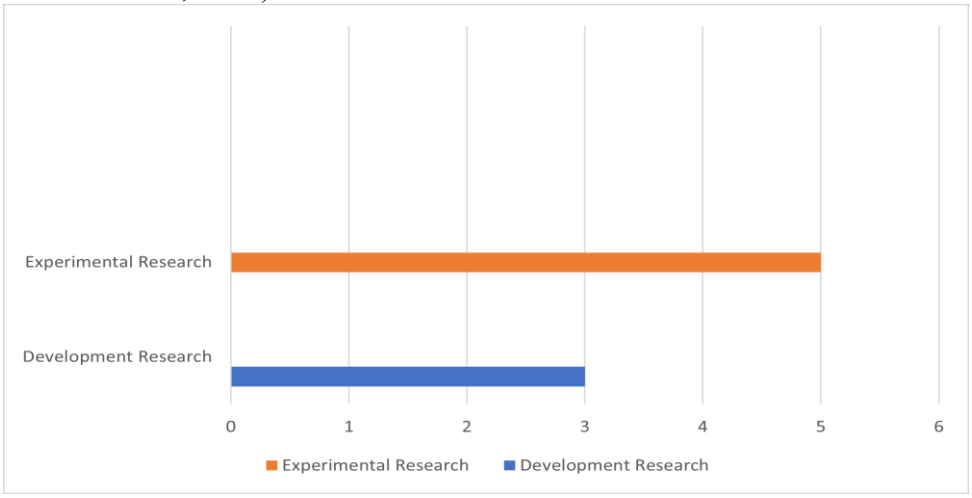

Figure 4. Type of Research STEM

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Figure 3 illustrates that, in the context of science learning, studies on STEM and creative thinking skills predominantly utilize experimental research methods compared to developmental research. Researchers used various research designs to collect data for their experimental studies. Among these, pre-test and post-test control group designs and post-test-only designs were commonly applied, representing standard quasi-experimental methods used to determine outcomes. These experimental approaches allowed researchers to assess the impact of specific interventions by analyzing the effects observed following their implementation.

RQ3. Result Study

The result shown in Table 3 indicate that STEM approach is successful in building students' creative thinking skill in science learning.

Table 3. Result Study

Author (Year)	Sample	Result
Pramesti et al., 2022.	Students of Class IX A and B	The research findings indicate that when STEM and project-based learning are combined, students' creative thinking capacity is increased. .
Nazhifah et al., 2023.	Students of Class X	The research results show that STEM-based e-learning developed for renewable energy topics has successfully improved pupils' capacity for original thought, supported by interactive and engaging features.
Sukma et al., 2023.	Students of Class X	The research findings indicate that the development of STEM-based E-books, particularly on environmental change topics, can successfully encourage students' capacity for creative thought.
Khalil et al., 2023.	Students of Class X and XII	The research findings show that a STEM-based curriculum substantially influences students' growth in terms of their capacity for creative thought compared to a conventional curriculum.
Tarihoran & Anas, 2023.	Students of Class XI	The research findings indicate that the STEM-integrated electronic student worksheet (E-LKPD) improves students' ability to think creatively. This tool is very valid, useful, and efficient in the topic of the senses system.
Simatupang et al., 2024	Students of Class VII C and D	Following the application of the project-based learning model with a STEM approach on the theme of environmental pollution, the research findings indicate that students' creative thinking abilities reached 91%, which is classified as very good.
Safitri et al., 2024	Students of Class X	The results of the study show that using the EDP model in conjunction with a STEM approach significantly improved students' capacity for creative thought on the subject of environmental pollution.
Ilafi et al., 2024	Students of Class VII C	The research findings show that the use of

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	STEM-based E-books can enhance students' creative thinking skills in the topic of temperature and heat.

Using the STEM approach as a teaching strategy is one efficient technique to promote creative thinking abilities. This model allows students to enhance their knowledge through cognitive processes. They are encouraged to stay focused on problems, conduct their own research, and actively apply their ideas to learn effectively and apply their knowledge. Students can actively contribute to developing their creative thinking skills through the STEM method. Students' creative thinking, open-mindedness, active learning, problem-solving, communication, teamwork, and interpersonal skills make their thinking talents extremely relevant in real-life circumstances where various issues arise in both personal and external contexts.

Implementing STEM approach can significantly improve high school students' creative thinking skills in science learning (Ilafi et al., 2024; Simatupang et al., 2024; Widyasmah et al., 2020). Because science includes both theoretical underpinnings and the practical application of those theories, research topics on science are important. STEM emphasises interdisciplinary learning grounded in real-life contexts and encourages students to think critically and creatively when addressing complex problems (Muttaqiin, 2023). Through this approach, students can explore issues using the information they have gathered and apply their knowledge to effectively solve those problems.

Table 3 demonstrates that the STEM (Science, Technology, Engineering, and Mathematics) approach consistently enhances students' creative thinking skills in science learning. Several studies highlight the effectiveness of STEM integration through various media and instructional methods. For instance, Pramesti et al. (2022) found that a low-carbon project-based learning model integrated with STEM fosters students' creative thinking abilities. Similarly, Nazhifah et al. (2023) and Sukma et al. (2023) showed that STEM-based e-learning and e-books developed for topics such as renewable energy and environmental change can stimulate creative thinking through interactive features. Khalil et al. (2023) emphasised that a STEM-based curriculum has a significantly greater impact on developing creative thinking skills than a conventional curriculum. Supporting these findings, Tarihoran and Anas (2023) found that students' creative thinking about the sensory system is improved by the STEM-integrated electronic student worksheet (E-LKPD), which is legitimate, useful, and efficient. Simatupang et al. (2024) noted that students' creative thinking skills reached an excellent level (91%) after using a STEM-based project-based learning strategy to the study of environmental pollution. Furthermore, Safitri et al. (2024) and Ilafi et al. (2024) respectively demonstrated that the use of the EDP model and STEM-based e-books significantly improved students' creative thinking skills in topics related to environmental pollution and temperature and heat. These findings confirm that the STEM approach is an effective pedagogical strategy for fostering students' creative thinking skills across various educational levels and scientific topics.

The articles reviewed share similarities and differences. Creative thinking skills and the STEM approach are consistently presented throughout the studies. Although not the only factors, variations can be observed in terms of research subjects, methodologies, topics, and sample sizes across the original articles. The findings of this study have both conceptual and practical implications for education. Conceptually, the results underscore the significant role of the STEM approach in fostering creative thinking skills, emphasizing that education should aim not only to impart knowledge but also to develop higher-order thinking and

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problem-solving abilities in students. Furthermore, the variation in research subjects, methods, topics, and sample sizes highlights the adaptability and applicability of the STEM approach across different educational contexts. Practically, these findings suggest that educators and curriculum designers can implement STEM strategies to promote creativity in the classroom, regardless of grade level or discipline. This underscores the importance of designing instructional methods that are interactive, inquiry-oriented, and adaptable to local conditions, thereby allowing educators to effectively develop their students' creative potential through STEM.

Conclusion

The research findings concluded that using STEM effectively builds students' creative thinking skills in science learning. The STEM approach enhances students' comprehension of scientific ideas and motivates them to solve problems using critical and creative thinking. According to the result study, incorporating science, technology, engineering, and mathematics components into science instruction enables students to collaborate, innovate, and apply their knowledge in real-world contexts. Additionally, factors such as teacher support, resource availability, and a conducive learning environment are crucial in successfully implementing this approach. This study has implications for developing more effective curriculum and teaching strategies to enhance students' creative thinking skills. The long-term effects of the STEM method on students' academic performance and capacity for creative thought in many educational situations require more investigation.

Recommendation

Recent research highlights the significant impact of STEM approach in fostering creative thinking among students, particularly in scientific learning. In response to these findings, educators are increasingly encouraged to integrate STEM more comprehensively into their teaching practices. This includes diverse instructional media and innovative learning models that convey scientific knowledge and actively engage students in problem-solving, critical analysis, and hands-on experimentation. By embedding STEM principles into everyday classroom activities, teachers can create dynamic and interactive learning environments that stimulate curiosity, promote intellectual exploration, and nurture creativity in scientific inquiry.

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