JOURNAL OF INNOVATION AND RESEARCH IN PRIMARY EDUCATION | ISSN 2829-775X
Vol. 4, No. 3, 2025, 467- 475
https://doi.org/10.56916/jirpe.v4i3.1343

A Study of the Development of STEM-Based Science Teaching Materials to Improve Learning Outcomes For Elementary School Students in the 2020-2025 Range

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Keywords
Science teaching materials
STEM
Learning outcomes

Article History
Received 2025-05-08
Accepted 2025-06-20

Abstract
Science, Technology, Engineering, and Mathematics (STEM) has been widely implemented in the learning process of Natural Sciences (IPA) to encourage improvements in student learning outcomes. This study aims to examine the development of STEM-based IPA teaching materials in improving the learning outcomes of elementary school students between 2020 and 2025. This study was conducted using the Systematic Literature Review (SLR) method by reviewing various studies and journals discussing the effectiveness of implementing STEM-based science teaching materials in science education at elementary schools. Through systematic review, 19 articles were identified, covering aspects such as teaching material design, teaching methods, measurability of learning outcomes, educational levels, as well as challenges and opportunities in implementing the STEM approach. The articles were obtained from various databases such as Google Scholar, ResearchGate, and SINTA-accredited journals. The results of the study indicate that the use of STEM-based science teaching materials significantly promotes improvements in conceptual understanding, critical thinking skills, skills in conducting scientific processes, student creativity, scientific communication, and student collaboration. From this study, it can be concluded that the development of STEM-based science teaching materials has great potential in improving the learning outcomes of elementary school students.

INTRODUCTION

Science education at the primary school level plays a significant role in fostering students' basic scientific concepts related to daily activities. Natural sciences does not only teach theory but requires students to have competence in critical reasoning, overcoming challenges and thinking creatively in applying the knowledge learned. These skills are skills that need to be mastered by students in the 21st century in order to become educated and skilled individuals. (Haryani et al., 2024) emphasized that the integration of 21st century skills requires students to be adaptive, innovative and able to make decisions based on scientific evidence. (Putri et al., 2024) stated that a science learning approach that emphasizes science literacy can encourage students to understand phenomena scientifically, thus strengthening the ability to think reflectively and reason. Science learning in elementary schools is not only about mastering material, but about forming scientific character and sustainable life skills.

Along with technological advances and the transformation of educational needs in the 21st century, the world of education is required to design learning approaches that are able to respond to the dynamics of real life. The Science, Technology, Engineering and Mathematics (STEM) learning approach is one strategy that is considered effective to answer this challenges. This approach not only combines the four main domains of science, technology, engineering and mathematics, but also encourages interdisciplinary integration that reflects real problems can be solved holistically. (Suryani et al., 2023) said that the application of the STEM approach in science learning in elementary schools help students understand concepts more deeply because they are invites to experience the scientific thinking process in solving problems that are relevant to their lives. In line with the opinion of (Subramaniam et al., 2025)

who emphasized that the STEM approach forms an analytical and systematic mindset, so that students can develop innovative solutions based on understanding the concepts that have been learned.

To be able to effectively accommodate the STEM approach in learning, teaching materials are needed that not only present material informatively, but are also designed in such a way as to encourage exploration, integration of concepts and contextual problem solving. Teaching materials are an important component that serves as a means to deliver material to students. Teaching materials can be written or unwritten materials that are systematically and attractively designed, including material, methods, limits and evaluation processes, with the aim of achieving the expected competencies. As explained by (Asi & Sesmiarni, 2023) teaching materials are important tools in the learning process that contain material content, delivery approaches, scope of discussion and evaluation procedures that are structured and attractive, to support the achievement of competencies that have been designed in learning objectives. Along with technological developments, teaching materials have been transformed into digital forms. Digital teaching materials not only contain text, but also integrate visual, audio, and other interactive elements to increase students involvement in the learning process. According to (Darmayanti & Amalia, 2024) digital teaching material is a teaching material that contains visual aspects, images, video, audio and so on, which there are elements of technology and computing integration.

Teaching materials in conventional and digital forms play a crucial role in supporting the learning process that provides support for the achievement of optimal student learning outcomes through a directed and appropriate process. Student learning outcomes describe the level of student mastery and understanding of teaching materials that include core competencies, basic competencies and achievement indicators that have been set in the curriculum (Soimah, 2019). According to Bloom (Putra et al., 2024) learning outcomes are classified into three domains, namely cognitive, affective and psychomotor, each of which plays an important role in the overall development of student competence. (Putra et al., 2024) further explained that (1) Cognitive domains such as knowledge, understanding, application, analysis, synthesis and evaluation, (2) Affective domains such as receiving, responding, appreciating and organizing, and (3) Psycomotor domains such as preparation, process and product.

Teaching materials that are prepared with a contextual, interesting approach and in accordance with student characteristics, will trigger active student involvement in the learning process, both cognitively, affectively and psychomotorically. This is reflected in students learning outcomes that are not only seen from the aspect of mastery of the material, but also from the ability of students to apply the knowledge and skills they have acquired to real situations. (Patika & Surmilasari, 2023) research states that the development of STEM approach science teaching materials using e-books is considered valid, practical and effective for improving students learning outcomes. Research by (Rahmawati et al., 2021) shows that the implementation of iSpring media in STEM-based science learning is effectively able to foster student creativity. The development of STEM-based teaching materials in the form of e-book and interactive digital media, is able to improve learning outcomes while encouraging students creativity in science learning.

Research by (Khoerunnisa et al., 2022) concluded that the development of student worksheet that integrates the STEM approach is considered to meet the eligibility criteria and make a positive contribution in improving students communication skills. Research by (Sumanti et al., 2025) stated that the development of STEM-based learning tools and project based learning in the form of teaching module and student worksheet was considered valid, practical and effective in improving students critical thinking skills and collaboration skills. The development of STEM-based learning tools, in the form of student worksheet and teaching modules, not only theoretically feasible and effective, but also able to encourage the strengthening of communication skills, critical thinking, and student collaboration.

The results of previous research show that: (1) The STEM approach can be implemented in science learning through various methods, including the utilization of various learning media, the application of certain learning models, and the development of learning tools such as printed/digital teaching materials, conventional/electronic modules, student worksheets both conventional and digital-based and (2) The integration of the STEM approach in the learning process has a multidimensional positive impact,

including improving academic learning outcomes, developing higher-level thinking skills (critical and creative), improving scientific process skills, and strengthening students' science literacy (Mariam Hoerunnisa et al., 2024).

Several previous studies have examined the implementation of the STEM approach in science learning, both through media, models, and learning tools. However, most of the focus is still limited to the form of implementation and general impact on learning outcomes, without systematically classifying the types of teaching materials, development models, and aspects of targeted learning outcomes. The review uses a systematic review approach by referring to literature procedures that involve the identification, selection, analysis and synthesis of relevant scientific articles. In this way, the results obtained not only describe the trend of developing STEM-based teaching materials, but also reveal the direction and impact on aspects of student learning outcomes more specifically. In addition, studies that specifically compile research at the elementary school level are still very limited. This gap shows the need for more focused and in-depth studies to map how STEM-based science teaching materials are developed and the extent of their effectiveness in improving various student learning outcomes.

In the span of 2020-2025, many innovations and developments in STEM-based science teaching materials were carried out to support the improvement of learning quality. The purpose of this study is to review various studies that have been conducted to observe the extent to which the effectiveness of the development of STEM-based teaching materials in improving the learning outcomes of elementary school students in the 2020-2025 range. The benefit of this study is to provide a comprehensive overview as a basis for formulating policies and developing more contextualized learning practices in elementary schools. In addition, the results of this study are also expected to be an empirical reference for teachers in selecting and designing teaching materials that have been proven effective in improving student learning outcomes, both from the aspects of knowledge, scientific process skills, and scientific attitudes.

METHODS

This research was conducted using the Systematic Literature Review (SLR) approach. SLR is a systematic and transparent approach to identifying, evaluating, and synthesizing research results relevant to a particular research question (Petticrew & Roberts, 2006). This approach is designed to minimize bias and increase the reliability and validity of conclusions generated from the reviewed literature. The steps of conducting an SLR referring to the flow proposed by (Petticrew & Roberts, 2006) are presented in the following Figure.

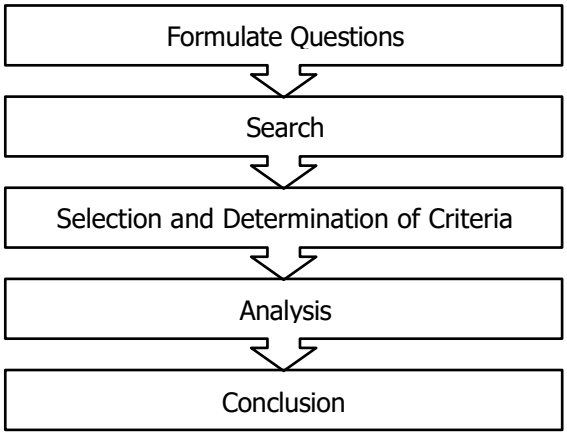

Figure 1. Flow of Systematic Literature Review

This process begins with the formulation of research questions as a basis for searching and evaluating relevant literature. The literature search was conducted through various databases such as Google Scholar, ResearchGate, and SINTA accredited journals with a publication deadline between 2020 and 2025. The search process used keywords in combination, such as: "development of science teaching

materials", "STEM approach", "student learning outcomes", and "STEM in elementary school". After that, the selection stage and the establishment of inclusion and exclusion criteria. To ensure that the data collected had high relevance and quality, inclusion criteria were applied, namely: (1) articles published within 2020-2025, (2) discuss the development of science teaching materials or STEM approaches, (3) research at the elementary school level, (4) include information or data related to student learning outcomes, and (5) published in journals that have gone through a *peer review* process. The exclusion criteria were: (1) articles that were opinion and did not provide empirical data, (2) did not focus on elementary school, (3) the research did not explicitly mention the STEM approach and (4) articles were not available in full text. Each article obtained was then written down, such as the author's name , year of publication, research method, object of study, and main findings. Here is the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta- Analyses) flowchart, which reflects the process of screening articles in a systematic review.

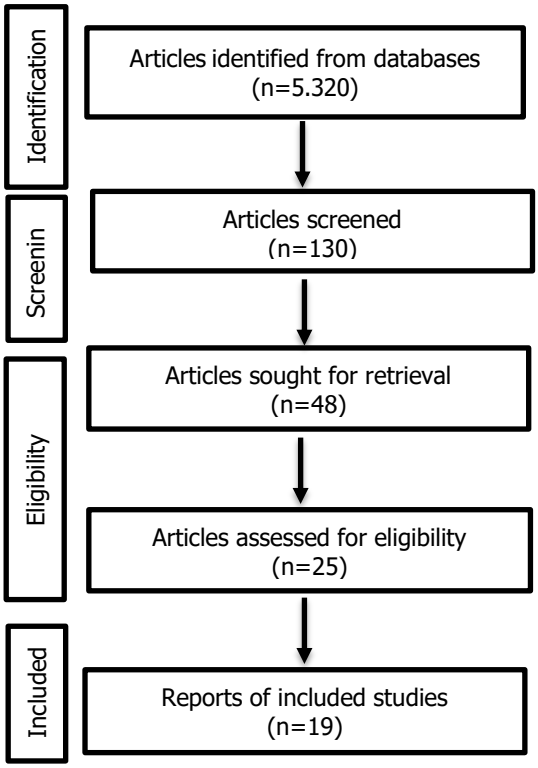

Figure 2. Flow of PRISMA

The next stage is data analysis conducted through a thematic approach by recognizing patterns and themes that emerge from the articles studied. Researchers read the articles repeatedly to find interrelationships between studies, both in terms of teaching material development strategies, forms of STEM integration, and their impact on student learning outcomes. Furthermore, similar findings were then grouped to facilitate drawing conclusions systematically and thoroughly.

RESULTS AND DISCUSSION

This review examines 19 scientific articles published from 2020 to 2025 with a focus on the effectiveness of developing STEM-based science teaching materials in improving learning outcomes of elementary school students. The development methods used mostly used *Research and Development* (R&D) with models such as 4D, ADDIE, and ASSURE. These models are considered to provide a systematic and applicable framework in designing teaching materials through validation and effectiveness testing stages. However, it can be critically observed that most of the studies have not included long-term implementation tests, and tend to be limited to small-scale trials with a one- group pretest-posttest design.

The forms of teaching materials developed are very diverse, ranging from interactive digital media, modules, interactive e-books, student worksheet and teaching modules that integrate STEM elements in contextual learning activities. This shows that the development of teaching materials is no longer limited to the delivery of material, but has developed into aspects of essential student competencies that are integrative, applicable, and oriented towards solving real-world problems. Based on the results of data analysis conducted, the following table illustrates the development of STEM-based science teaching materials.

Table 1. Recap of the Findings of the Literature Review of STEM-Based Science Teaching Materials Development 2020-2025 Range

No.	Author	Types of Teaching Materials	Aspects of Learning Outcomes	Development Model	Development Outcome or Effect
1.	(Ristiani et al., 2020)	Lectora inspire media using version 12	Creativity	ASSURE	Worth using
2.	(Rahmawati et al., 2021)	iSpring media	Creativity	R&D Model ASSURE	The media is feasible to use and able to develop student creativity
3.	(Nurmala et al., 2021)	Media articulate storyline 3	Creativity	ASSURE	Feasible and effective
4.	(Salam et al., 2021)	textbook	Creativity	ADDIE	Worth using
5.	(Nisa et al., 2021)	Student worksheet	Sains literacy	Borg & Gall	Very valid
6.	(Ismail & Wahidin, 2022)	A straw bridge project, a simple speaker and a balloon powered car	Scientific communication	Quantitative descriptive	The game project is able to train students scientific communication
7.	(Khoerunnisa et al., 2022)	Student worksheet	Comunication	ADDIE	Feasible and effective
8.	(Patika & Surmilasari, 2023)	E-book	Learning outcomes	ADDIE	Highky valid, practical and effective
9.	(Adhiati et al., 2023)	Student worksheet	Kolaborasi	ASSURE	Improved collaboration skills
10.	(Cahyono et al., 2023)	Assessment sheets, student worksheets, student teaching material and learning implementation plans	Critical thinking and problem solving	Dick & Carey	Significant improvement
11.	(Nurlatifah et al., 2023)	Teaching module	Curiosity	ASSURE	Worth using
12.	(Mellani Saputri & Patonah, 2023)	Teaching module	Science process skills	ADDIE	Valid, practical and effective
13.	(Puspitasari et al., 2024)	Teaching module	Scientific thinking	R&D Model ADDIE	Valid, practical and effective modules for scientific thinking
14.	(Septiadevana & Abdullah*, 2024)	STEM teaching modules and project based learning	Science literacy and critical thinking	Qualitative	Modules fit to develop 21st century skills
15.	(Nihayati et al., 2024)	E-modules	4C (communication, collaboration, critical and creative)	Plomp	Valid and practical to use
16.	(Fauziati et al., 2024)	Teaching module	Questioning ability	ADDIE	Valid and feasible
17.	(Siti Rofikoh et al., 2024)	E-modules	Creativity	ADDIE	Practical and effective
18.	(Sumanti et al., 2025)	Teaching module and student worksheet	Critical thinking and collaboration	R&D Model 4D	Effective toolkit improves students 4C skills
19.	(Ningsih et al., 2025)	Teaching materials based on STEM-R	Student learning outcomes	R&D Model ADDIE	STEM-R teaching materials effectively improve science learning outcomes of elementary school students

The results of this study show that the development of STEM-based science teaching materials makes a real contribution to improving student learning outcomes, both from cognitive, affective and psychomotor aspects. To get a systematic picture of the aspects of learning outcomes that are improved through the development of STEM-based science teaching materials, the following table presents a recapitulation of 19 articles that have been analyzed.

Table 2. Recapitulation of Learning Outcome Aspects

No.	Aspects of Learning Outcomes	Total Research
1.	Creativity	6
2.	Critical thinking	4
3.	Collaboration	3
4.	Science literacy	2
5.	Learning outcomes / concept understanding	2
6.	Scientific communication	3
7.	Scientific thinking	1
8.	Questioning ability	1
9.	Problem solving	1
10.	Curiosity	1
11.	Science process skills	1

Based on Table 2, the most dominant aspects studied include creativity (6 articles), critical thinking (4 articles), collaboration (3 articles), scientific communication (3 articles), and general learning outcomes and science literacy (2 articles each). Meanwhile, other aspects such as science process skills, questioning ability, curiosity, problem solving and scientific thinking have only been addressed to a limited extent. The creativity aspect is the most dominant focus in the studies reviewed, indicating that the development of STEM-based teaching materials is very potential in encouraging students' ability to generate new, innovative, and original ideas in solving contextual problems. This is inseparable from the characteristics of the STEM approach which requires active involvement of students in exploring, designing, and reflecting on solutions to real problems, as seen in the research of (Ristiani et al., 2020) and (Rahmawati et al., 2021).

Meanwhile, aspects of critical thinking, science literacy, and collaboration are also often the learning outcomes measured. Strengthening students' critical thinking skills is reflected in the research of (Cahyono et al., 2023) and (Sumanti et al., 2025) through the integration of STEM approaches in project-based and inquiry-based learning models. Critical thinking skills are considered vital in facing the challenges of the 21st century that demand the ability to analyze, evaluate, and make decisions based on data and logic. On the other hand, science literacy is positioned as a basic skill in understanding the surrounding world scientifically, which is obtained through explorative and reflective activities, as shown in the study of (Nisa et al., 2021).

Interestingly, although aspects such as *problem solving*, questioning skills and curiosity have not been widely studied, their presence still shows that the STEM approach opens space for the development of essential learning dimensions that are often marginalized in conventional learning. Various studies show that with the development of STEM-based science teaching materials, students become more interested, actively involved, and have the opportunity to think, create, and reflect on the learning process more deeply.

This finding strengthens the results of previous studies such as those presented by Hoerunnisa et al. (2024). However, there are differences in the focus and depth of the study results. Hoerunnisa's study emphasized the implementation of STEM through various learning methods and media in general, such as print/digital modules and learner worksheets, and highlighted the multidimensional impact of

STEM which includes improving academic learning outcomes, critical-creative thinking skills, scientific processes, and science literacy at various levels of education. While this study specifically discusses the impact of STEM-based science teaching materials with measurable results, such as significant improvements in concept understanding, science process skills, creativity, scientific communication, and student collaboration, especially in elementary schools.

This study shows a shift in the direction of research to a broader domain, including affective aspects and scientific skills. This shows that the trend of developing STEM- based teaching materials is starting to consider the character of students more fully, not only as recipients of information, but as active learners who are involved in the scientific process. Therefore, there are further research opportunities to explore in depth how the development of STEM teaching materials can support a broader and more comprehensive dimension of learning outcomes.

CONCLUSIONS

Based on a systematic review of 19 scientific articles published between 2020 and 2025, it can be concluded that the development of STEM-based science teaching materials in elementary schools makes a significant contribution to improving overall student learning outcomes. The teaching materials developed are very diverse, ranging from interactive media, teaching modules, learning tools, student worksheets, to project- based activities and are proven to be able to improve various aspects of learning outcomes, such as concept understanding, critical thinking, creativity, collaboration, science literacy, scientific communication, science process skills, problem solving and so on. Most studies use structured development models, such as 4D, ADDIE, and ASSURE, with an R&D approach. This shows that the development of teaching materials is carried out through systematic stages, involving validation and effectiveness tests, so that the products produced are relevant and applicable. The development of STEM-based science teaching materials can be seen as one of the potential strategies in creating a meaningful learning process at the basic education level. However, this study has limitations, related to limited access to foreign language studies and articles using relatively simple research designs. For this reason, future research is expected to develop STEM-based teaching materials that target aspects of learning outcomes that have not been widely touched, such as curiosity and the ability to ask questions, and use more diverse and in-depth research approaches.

ADVICE

Suggestions for teachers and educational practitioners are to start developing and using STEM-based teaching materials that are contextual, adaptive, and encourage exploration and real problem solving. For curriculum developers and school principals, policy support and the provision of facilities that support STEM implementation are needed, including continuous teacher training so that they have a deep understanding of the philosophy and practice of STEM-based learning.

For future researchers, it is recommended to conduct an implementation study of the developed teaching materials, with a focus on student engagement, implementation constraints, and long-term impact. Classroom action or longitudinal studies can provide greater insight into the long-term effectiveness of this approach in various primary school contexts.

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