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Review paper

# Trends in STEM-Based Physics Education Research (2016–2025): A Systematic Literature Review

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## ABSTRACT

The integration of STEM (Science, Technology, Engineering, and Mathematics) in physics education is gaining increasing global attention due to its role in developing 21st-century competencies such as critical thinking, creativity, and technological literacy. This study presents a systematic literature review (SLR) of STEM-based physics education research published in Scopus-indexed journals between 2016 and 2025. Following the PRISMA protocol, 57 articles meeting the criteria were analysed through thematic and descriptive synthesis. The results of the analysis indicate a significant increase in research activity after 2018, with a peak in publications occurring in 2023. Indonesia, Malaysia, and the United States emerged as the main contributors. This review also revealed that Project-Based Learning (PjBL) and Problem-Based Learning (PBL) are the most widely used pedagogical models, whilst technology-based strategies such as Arduino-based digital learning and the flipped classroom appear to be growing in prominence. Although STEM research is growing globally, there remains a gap in theoretical coherence, namely that most studies have not elucidated how the integration of STEM components (S, T, E, M) is applied in research. Furthermore, no studies have examined teachers' digital readiness when implementing STEM in physics education, and there are limitations in studies across certain educational levels. Future research is recommended to use a longitudinal and mixed-methods approach to examine how STEM integration can enhance scientific literacy and higher-order thinking skills in physics education.

**Keywords:** STEM, physics education, systematic literature review, technology integration, 21st-century skills

STEM education has become a cornerstone of 21st-century learning, sparking curiosity, creativity, and practical reasoning in young students. In the early elementary grades, a STEM-based approach helps students bridge the gap between disciplines and apply their knowledge to real-life challenges (Ismail et al., 2026), which serves as the foundation for navigating the challenges of the digital era and the Fourth Industrial Revolution. In response to these demands, the STEM (Science, Technology, Engineering, and Mathematics) approach has emerged as a transformative, interdisciplinary educational framework capable of integrating theoretical concepts with real-world applications. Within the context of physics education, STEM integration holds significant potential to bridge the gap between abstract concepts and real-world phenomena that often transcend disciplinary boundaries. This integration not only enhances conceptual mastery but also fosters higher-order thinking, problem-solving skills, and scientific literacy among students (Asrizal et al., 2023; Nazifah & Effendi, 2024). Despite its growing prominence, the integration of STEM in physics education remains conceptually and methodologically misaligned. Many studies employ the term "STEM integration" without clearly specifying whether it refers to curricular reform, instructional models, media design, or assessment frameworks (Dominguez et al., 2024; Heard et al., 2025; Moya & Camacho, 2024; Oprea et al., 2023; Shahidullah & Hossain, 2022; Tramonti et al., 2023). The lack of definitional clarity and scope has led to inconsistencies in implementation and has hindered theoretical progress in STEM education. Furthermore, most existing studies remain largely descriptive—mapping broad trends rather than probing the depth of integration or the underlying pedagogical mechanisms. This indicates that, whilst STEM has been widely adopted, systematic scientific investigations into the forms and effectiveness of STEM integration in physics education remain relatively limited (Grewe, 2025).

Over the past decade, a substantial body of research has demonstrated that Project-Based Learning (PjBL) and Problem-Based Learning (PBL) are the most frequently employed pedagogical models within the STEM framework for physics instruction (Sulaiman et al., 2023). These pedagogical innovations are often combined with digital technologies such as Arduino, Virtual Reality, and Augmented Reality, which have proven effective in enhancing students' conceptual understanding and critical thinking abilities (Acar et al., 2025; Bodensiek et al., 2019; Lai & Cheong, 2022; Sung et al., 2019; Türkoğuz & Kayalar, 2021). Moreover, the development of STEM-based physics learning modules has contributed significantly to the enhancement of both conceptual mastery and essential 21st-century skills. Nevertheless, representational competence, technological literacy, and assessment literacy have received comparatively less scholarly attention, whilst most research continues to emphasise critical and creative thinking (Gebre, 2018; Mafarja et al., 2024; Pantiwati et al., 2021; Danial et al., 2026).

In addition to theoretical limitations, practical challenges also persist in the classroom implementation of STEM in physics education. Teachers often struggle to design genuinely interdisciplinary lessons due to limited experience and insufficient understanding of STEM principles ( Köşger & Görgülü, 2025; Mitani et al., 2022; Nazifah & Effendi, 2024; Syukri et al., 2026; Webb, 2026). Insufficient pedagogical readiness and inadequate educational infrastructure further hinder effective implementation. Although the need for STEM integration is widely recognised, its realisation remains inconsistent and context-dependent (Asrizal et al., 2023; Khalil et al., 2023; Sarnita et al., 2021). These issues underscore the need for a systematic and comprehensive review of global research trends in STEM-based physics education to provide a clearer picture of its conceptual development and practical applications.

### Research objectives and questions

The study aims to conduct a Systematic Literature Review (SLR) combined with a bibliometric mapping analysis of global publications on STEM-based physics education between 2016 and 2025. This approach seeks to analyse methodological patterns, contributions by countries and leading researchers, dominant instructional models, and under-explored research areas. Employing the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol ensures a transparent and rigorous review process. The findings are expected to provide a more coherent conceptual foundation for understanding how STEM integration is operationalised in physics education, whilst identifying promising directions for future research aligned with 21st-century educational needs.

Based on these objectives, this study formulates the following Research Questions (RQs):

- RQ1: Which countries have published the most articles on STEM in physics education during the period 2016–2025?
- RQ2: What types of integration are most commonly implemented in STEM-based physics education?
- RQ3: At which educational levels has STEM integration been most extensively examined?
- RQ4: What research gaps can be identified for future studies in the field of STEM-based physics education?

Through this systematic review, it is expected that a comprehensive overview of global research trends in STEM-based physics education will be obtained, thereby strengthening both the conceptual and empirical foundations for developing innovative, contextual, and future-oriented physics learning that aligns with the competencies required in the 21st century.

## METHODS

This study is a systematic literature review, the steps of which include formulating research questions, identifying relevant literature, selecting and extracting data, and synthesis (Xiao & Watson, 2019). The writing of this literature review article began with the identification of articles sourced from the Scopus database, conducted by the author in September 2025. The identified articles are those in the field of STEM in Physics Education over the last 10 years (2016–2025). This study adopts a qualitative narrative review approach, focusing on thematic synthesis of the literature without conducting a statistical meta-analysis. Although primarily qualitative in nature, this review incorporates a descriptive quantitative synthesis (e.g., frequency calculations based on publication frequency, country, theme, and how STEM is integrated into physics education). The keywords and filters used for the article search are as follows:

1. 57 documents were retrieved using the keywords ((TITLE-ABS-KEY(STEM) AND TITLE-ABS-KEY("Physics Education" OR "Physics Teaching" OR "Physics Pedagogy")) AND NOT TITLE-ABS-KEY(chemistry OR biology OR mathematics OR "chemical education" OR "biological education" OR "math education" OR "environmental education") AND PUBYEAR >2015 AND PUBYEAR <2026 AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (OA, "all"))
2. 119 documents retrieved with the keywords ((TITLE-ABS-KEY(STEM) AND TITLE-ABS-KEY("Physics Education")) AND NOT TITLE-ABS-KEY(chemistry OR biology OR mathematics OR "chemical education" OR "biological education" OR "math education" OR "environmental education") AND PUBYEAR >2015 AND PUBYEAR <2026 AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (OA, "all")) AND (LIMIT-TO (SUBJAREA, "SOCI"))
3. 121 results found ((TITLE-ABS-KEY(STEM) AND TITLE-ABS-KEY("Physics Learning")) AND NOT TITLE-ABS-KEY(chemistry OR biology OR mathematics OR "chemical education" OR "biological education" OR "math education" OR "environmental education") AND PUBYEAR >2015 AND PUBYEAR <2026 AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (OA, "all")) AND (LIMIT-TO (SUBJAREA, "SOCI")).
4. 73 records found ((TITLE-ABS-KEY(STEM) AND TITLE-ABS-KEY("Physics Teaching")) AND NOT TITLE-ABS-KEY(chemistry OR biology OR mathematics OR "chemical education" OR "biological education" OR "math education" OR "environmental education") AND PUBYEAR >2015 AND PUBYEAR <2026 AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (OA, "all")) AND (LIMIT-TO (SUBJAREA, "SOCI"))
5. 13 documents retrieved ((TITLE-ABS-KEY(STEM) AND TITLE-ABS-KEY("Physics Pedagogy")) AND NOT TITLE-ABS-KEY(chemistry OR biology OR mathematics OR "chemical education" OR "biological education" OR "math education" OR "environmental education") AND PUBYEAR >2015 AND PUBYEAR <2026 AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (SRCTYPE, "j")) AND (LIMIT-TO (OA, "all")) AND (LIMIT-TO (SUBJAREA, "SOCI"))

A search using several specific keywords yielded 383 documents, which were then compiled into a single folder to remove duplicate records. The screening process yielded 318 articles, which were subsequently filtered using a selection process based on titles and abstracts, with the aim of eliminating articles that were not research outputs (e.g., review articles, content analyses not related to the integration of STEM in physics education or learning) and excluding articles whose participants were not secondary school pupils, teachers, or university students. The aim was to ensure that the review process accurately represents the development of STEM in the field of physics education as applied in secondary schools and higher education. The terms ‘chemistry’, ‘biology’, ‘mathematics’, ‘chemical education’, ‘biological education’, ‘maths education’, and ‘environmental education’ were excluded, as their inclusion would broaden the scope of this study. This decision ensures that the research focuses solely on examining the application of STEM in physics education, thereby identifying innovations in its implementation.

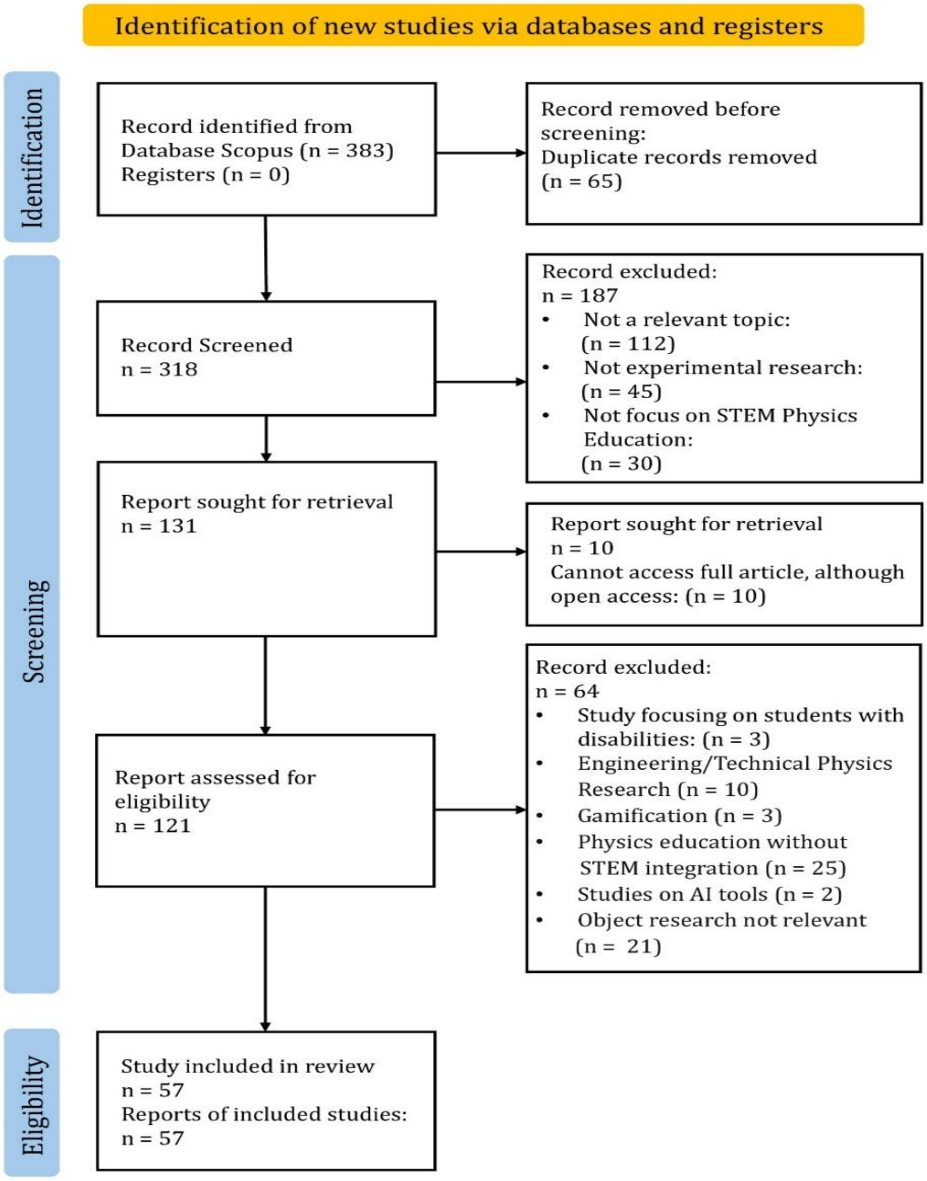
The search in Scopus was restricted to open-access (OA) publications to ensure the availability of full-text articles during the screening process. Furthermore, the search was restricted to the subject field 'Social Sciences' (SOCI) to maintain relevance to the research focus on pedagogical and learning aspects within physics education. As an interdisciplinary field, physics education articles can be found in both the Social Sciences and Pure Physics categories. This restriction was applied to ensure that the analysed articles consistently address educational dimensions, rather than merely focusing on the development of physics concepts. Consequently, the findings of this study reflect trends in open-access publishing within the context of the social sciences and may not be generalisable to all STEM education research published in pure physics journals. This limitation is acknowledged as a potential source of bias.

This study adheres to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure a transparent and rigorous methodology, as illustrated in Figure 1 (Page et al., 2021). All reference management was carried out using Mendeley. Following abstract screening, 57 articles remained; these were then read, analysed, categorised, and coded using a spreadsheet programme, without the use of additional qualitative analysis software (e.g., NVivo). In addition to the categorisation described above, this study aims to present the results of the identification of emerging research trends and recommendations for future research.

To visualise research trends and recommendations for future research, the Biblioshiny software was used (Aria & Cuccurullo, 2017). The visualisation of research trends was achieved through a thematic map showing the density and centrality of various topics. Density is represented on the vertical axis, indicating the relevance of a topic based on the number of studies, whilst centrality is represented on the horizontal axis, indicating the extent to which a topic is integral to the field. The combination of these two factors helps to identify key research themes and suggests areas for future research in STEM physics education.

**Figure 1**

*PRISMA research flowchart*



## RESULT AND DISCUSSION

### Trends in countries that have published the most articles on STEM in physics education

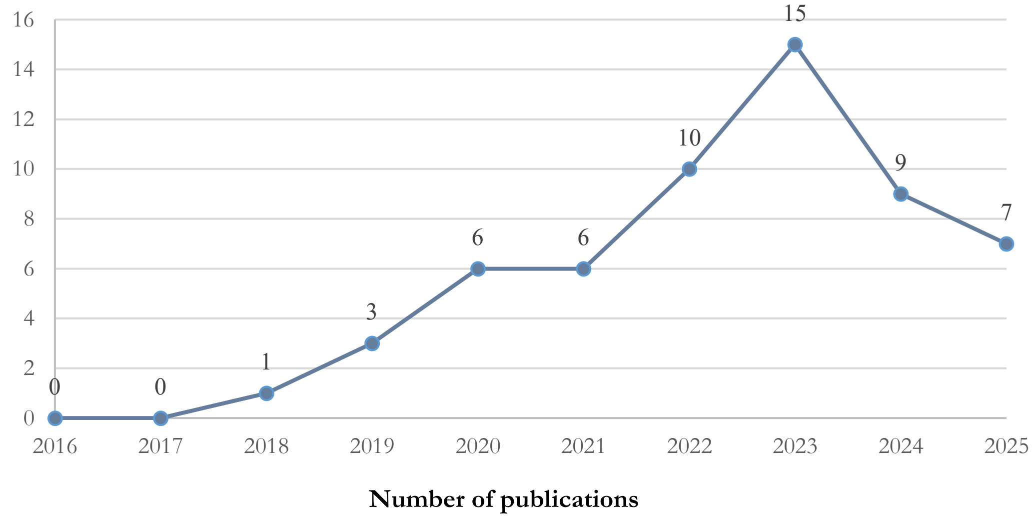
Following the screening process, 57 of the 383 identified articles were included for in-depth analysis. Many articles were excluded because most addressed STEM in a general context, rather than specifically focusing on STEM in physics education. Furthermore, several articles focused on literature reviews to identify trends, students' and teachers' perceptions of STEM learning, responses to learning involving students with disabilities enrolled inintroductory physics courses, assessments of STEM learning outcomes, the use of AI and ChatGPT as learning feedback, the influence of social factors related to physics learning ability, teachers' confidence levels regarding the use of STEM, and case studies that had not yet integrated STEM into physics teaching. These topics were excluded so that the findings of this study could provide clear and targeted answers to the research questions and accurately represent the application of STEM in physics education and its impact on the quality of physics learning. This literature review is limited to the subjects of secondary school pupils, university students, and physics teachers. This is because physics education is primarily introduced at the secondary school and university levels, and its implementation is carried out by physics teachers in schools. The increasingly sophisticated development of the digital era has influenced the use of digital media to support quality learning, particularly regarding how technology plays a vital role in enhancing students' understanding of physics concepts. Various types of learning models, methods, approaches, instructional strategies, and STEM-based technologies in physics education will be explained in detail in the findings of this article.

Figure 2 shows the number of research publications on STEM in Physics Education over the last 10 years (2016–2025). In 2016–2017, no research was found on the specific integration of STEM within physics education. Subsequently, in 2018, there was research related to STEM in physics education, albeit at a very low frequency. Research on STEM in physics education continued to increase after 2018, with the highest number of publications peaking in 2023. This significant increase was likely due to the spread of the COVID-19 pandemic between 2020 and 2023, which substantially impacted the learning process. All learning activities in schools were suspended and shifted to an online learning system. In such a situation, there were numerous challenges to be addressed. Teachers were required to be creative in developing technology-based learning resources to facilitate active student engagement during distance learning. These conditions stimulated the emergence of various learning innovations that integrated the STEM approach with digital technology as a 21st-century learning solution.

Although pedagogical approaches that support STEM (inquiry-based learning and problem-solving) have long been part of physics education, research explicitly employing integrated STEM (iSTEM) and integrated STEAM frameworks has only experienced a significant rise in publications since the mid-2010s (around 2014–2018). This aligns with the growing global policy push for vocational education reform. Empirical evidence from the analysed studies, such as research on video perception (Pérez-Navarro et al., 2021), confirms that the adoption of STEM has now become increasingly mainstream, particularly in Introductory Physics courses for Engineering students. The surge in iSTEM research, particularly that integrating physics and engineering, is driven by a global shift in curriculum paradigms. Frameworks such as the Next Generation Science Standards (NGSS) emphasise that science learning can no longer be isolated. The NGSS explicitly integrates Science and Engineering Practices (SEPs) as a core dimension, requiring students to act like engineers by designing solutions and optimising their designs (NGSS Lead States, 2013).

**Figure 2**

*Distribution of Articles by Year of Publication*

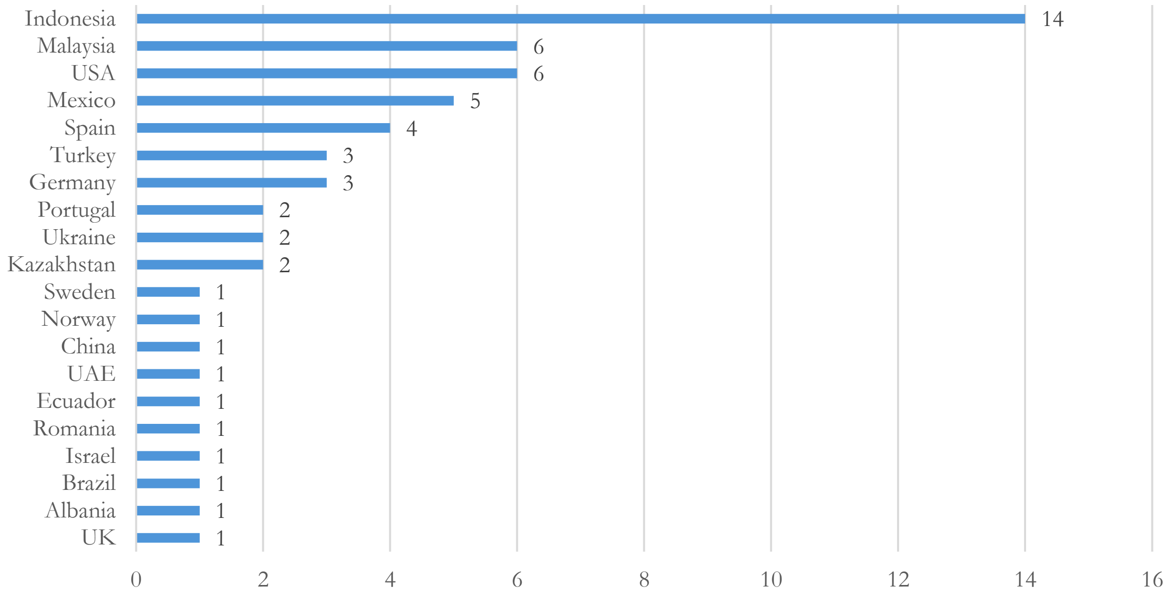


Based on the data on the number of publications, STEM research remains highly dynamic and has significant potential for further development (see **Figure 2**). Countries across almost every part of the world have been actively conducting studies on STEM integrated into physics education and publishing findings related to STEM research in this field. A total of 57 analysed articles originated from 20 countries, with the distribution presented in Figure 3. The countries conducting the most (dominant contributors to) research on the integration of STEM in physics education are Indonesia (14 articles), Malaysia (6 articles), the USA (6 articles), and Mexico (5 articles). Other countries such as Spain, Turkey, Germany, Portugal, Ukraine, and Kazakhstan are also actively conducting research in the field of STEM integration in physics education, albeit to a lesser extent. This classification is based on the affiliation of the first author as stated in the article metadata. These findings indicate that Southeast

Asia and the United States have been the primary hubs for research activity on STEM integration in physics education over the past decade (2016–2025). The high volume of publications from the United States can be explained by its role as a centre for the development of early STEM frameworks and funding (Kelley & Knowles, 2016). Meanwhile, the surge in contributions from Indonesia and Malaysia (see Figure 3) is most likely a reflection of strong regional policy responses. These Southeast Asian countries are actively investing in curriculum reform and teacher professional development to enhance STEM competencies as part of their national education development goals (OECD, 2018).

**Figure 3**

*Countries publishing articles in the field of STEM Physics education during 2016–2025*



### Trend of educational levels: Integration of stem in physics education

The categorisation of the 57 reviewed articles reveals the distribution of STEM research subjects in physics education, divided into three main groups: lower secondary school students (7 publications), upper secondary school students (26 publications), and higher education (24 publications) (**Figure 4**)

**Figure 4**

*Subjects in the field of STEM physics education during 2016–2025.*

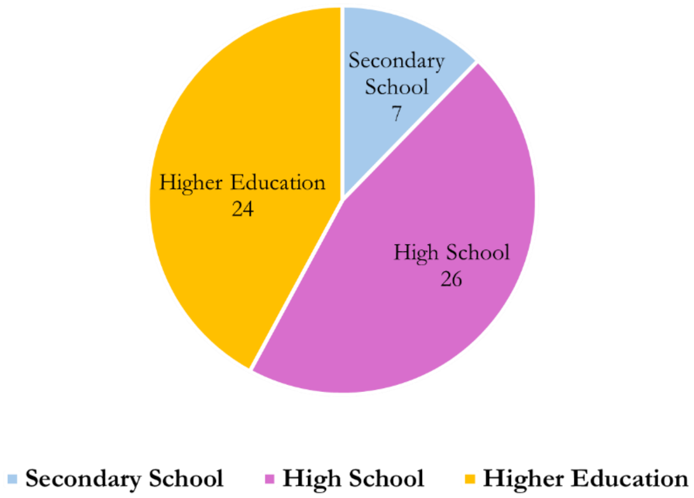


**Figure 4** indicates that the most common subjects in STEM research applied to physics education are upper secondary school students, followed by students in higher education (particularly in physics and engineering disciplines), and lower secondary school students. These findings suggest that the application of the STEM approach is more frequently directed towards secondary and higher education levels, where students and

undergraduates are deemed to have attained sufficient cognitive and conceptual understanding to grasp the relationships between science, technology, engineering, and mathematics within the framework of physics. Conversely, research involving primary school pupils is extremely limited. This is likely due to limitations in abstract thinking ability at that age, which necessitate the adaptation of STEM learning in physics to more concrete and contextually relevant forms. Research involving teachers has not yet been found in the reviewed articles, although teachers play a vital role in the implementation of the STEM curriculum. This situation suggests that research focusing on the professional development of physics teachers within the STEM context remains an area that warrants further investigation. These findings are reinforced by research conducted by (Margot & Kettler, 2019), which shows that secondary school students respond positively to STEM learning, as it enhances motivation and conceptual understanding.

### Conceptualisation of STEM integration in physics education

Based on the synthesis of 57 eligible articles, various types of STEM integration have been applied in physics education (as shown in **Table 1** in APPENDIX).

Both of the findings empirically demonstrate that the conceptual fragmentation criticised in the introduction does indeed occur. Almost half of the literature (40%) interprets STEM as a pedagogical model, whilst the other half (60%) interprets STEM as the integration of technology. This fundamental difference in understanding means that studies claiming to implement "STEM integration" actually represent distinct conceptual frameworks. Consequently, the accumulation of knowledge in this field is hindered because findings from one conceptual group cannot be directly compared with those from another.

To address the theoretical gap identified in the introduction, namely: “Despite its growing prominence, the integration of STEM in physics education remains conceptually and methodologically misaligned. Many studies employ the term “STEM integration” without clarifying whether it refers to curricular reform, instructional models, media design, or assessment frameworks (Dominguez et al., 2024; Heard et al., 2025; Moya & Camacho, 2024; Tramonti et al., 2023). This review systematically analyses how the 57 articles examined conceptualise and operationalise the components of STEM. Based on an analysis of the ‘Type of STEM Integration’ column in **Table 1** (see APPENDIX), it was found that STEM integration is conceptualised in two main forms.

Firstly, 23 articles (40%) conceptualised STEM as a pedagogical model. This category was dominated by Project-Based Learning (PjBL) and Problem-Based Learning (PBL), and included other approaches such as inquiry-based learning, discovery learning, STEM experiments, and hands-on activities. In these articles, STEM is operationalised through student-centred, project- or problem-based learning approaches. A critical finding from this analysis is that the majority of articles in this category do not explicitly explain how the four components of STEM (Science, Technology, Engineering, Mathematics) are integrated in a systematic and balanced manner. STEM often functions as a re-labelling of pre-existing pedagogical practices (PjBL and PBL), without clearly articulating the added value of the STEM framework beyond these established models.

Secondly, as many as 34 articles (60%) conceptualise STEM as the integration of technology or tools. This category is dominated by the use of Arduino, Augmented Reality (AR), Virtual Reality (VR), various simulation software, e-modules, and digital teaching materials (see **Table 1** in APPENDIX). The primary focus in these articles is on the development or application of specific technological tools. A critical finding is that although technology is one of the pillars of STEM, its integration is often reductionist in nature; that is, technology is used as a learning aid, but its relationship with science, engineering, and mathematics is not explicitly articulated. In many cases, STEM is reduced to merely the ‘use of technology in physics education’. Several studies have been developed, such as research conducted by Winarto et al. (2026) about integrating Mobile Technology in Inquiry-Based Instruction for Sustainable and Innovative Learning in Higher Education. This study demonstrates how digital instruction can be made user-friendly, thus encouraging learner development focused on sustainability, creativity, and wisdom. These findings offer valuable advice for higher education institutions aspiring to build inclusive, efficient, and innovative STEM-based learning experiences.

Both of the above findings empirically demonstrate that the conceptual fragmentation identified and critiqued in the introduction does indeed occur. Almost half of the literature (40%) interprets STEM as a pedagogical model, whilst the other half (60%) interprets STEM as the integration of technology. This fundamental difference in understanding means that studies claiming to implement "STEM integration" in fact represent divergent conceptual frameworks. Consequently, the accumulation of knowledge in this field is significantly constrained because findings from one conceptual group cannot be directly compared with those from another.

#### *STEM as curriculum reform*

A small proportion of studies (4.7%) conceptualise STEM integration as a fundamental restructuring of the curriculum. In these studies, STEM is positioned not merely as a pedagogical strategy, but as an organisational framework that redefines learning objectives, the sequence of content, and cross-disciplinary connections. For example, Khalil et al. (2023) examined a STEM-based curriculum within the International Baccalaureate (IB) framework, where physics concepts are deliberately interwoven with engineering design challenges. Similarly, Dominguez et al. (2024) investigated integrated physics-mathematics courses designed to break down the barriers of traditional disciplinary boundaries. What distinguishes this category is the explicit articulation of how the four STEM domains are interconnected at the curriculum level, a level of clarity that is not consistently observed in other categories.

### *STEM as a pedagogical model*

The majority of studies (n = 40%) operationalise STEM primarily through specific pedagogical models, the most prominent being Project-Based Learning (PjBL) and Problem-Based Learning (PBL). In this category, the term 'STEM integration' is often used interchangeably with the adoption of these instructional approaches. Whilst PjBL and PBL are indeed aligned with STEM principles, as both emphasise student-centred, collaborative learning grounded in real-world problem contexts, the analytical challenge lies in the fact that these models existed long before the current STEM movement. Consequently, many studies in this category fail to explain what the "STEM" label contributes beyond what is already inherent in PjBL or PBL. These findings suggest that in nearly half of the reviewed literature, STEM serves a limited function as a distinct conceptual framework and is instead primarily employed as a re-labelling of established pedagogical practices.

### *STEM as the integration of technology or tools*

The majority of studies (n = 60%) conceptualise STEM integration through the use of digital technologies and tools. In this category, STEM is operationalised as the use of specific digital tools or platforms, including Arduino microcontrollers (Çoban & Erol, 2025; Pickup & Roch, 2025), Augmented Reality (Bodensiek et al., 2019), Virtual Reality (Campos et al., 2022), and simulation software (Gutiérrez et al., 2022). Although these studies often claim to implement "STEM education", the integration between science, engineering, and mathematics is frequently implicit rather than explicit. The primary focus is on the technological component, with limited articulation of how technology mediates the other STEM domains. This category reveals a critical point of conceptual fragmentation: when STEM is reduced to "using technology in learning", the interdisciplinary essence of STEM, namely the synthesis of the four domains, becomes obscured.

### *Synthesis: Mapping fragmentation*

The three categories described above are not merely differences in classification, but rather represent fundamentally different understandings of the meaning of STEM integration in physics education. Studies that conceptualise STEM as a curriculum reform operate on different assumptions, objectives, and evaluation criteria compared to studies that conceptualise STEM as the adoption of technology. However, all are published under the same umbrella of 'STEM integration'. This conceptual fragmentation has significant implications: it hinders theoretical progress, complicates meta-analysis, and makes it difficult for educators to translate research findings into classroom practice. The findings in this section empirically substantiate the theoretical gap identified in the introduction.

### *Depth of stem integration: From superficial to interdisciplinary*

In addition to how STEM is conceptualised, this review also assesses the depth of cross-disciplinary integration. Based on the framework proposed by Kelley & Knowles (2016). This study evaluates whether studies achieve superficial integration, where STEM is primarily utilised as a contextual support for physics learning, or genuine interdisciplinary integration, where the four STEM domains are explicitly synthesised to address complex problems. This analysis reveals a continuum that further reinforces the conceptual fragmentation identified earlier.

### *Superficial integration*

Around 60% of the studies (n = 34) demonstrated what can be characterised as superficial integration. In these studies, STEM served primarily as a context or motivation for learning physics concepts, whilst the engineering and mathematics components remained underdeveloped. For example, studies using Arduino for physics experiments often emphasise data collection and visualisation (science and technology), but provide limited opportunities for students to engage in engineering design processes such as iterative prototyping or optimisation under constraints, or mathematical modelling beyond basic calculations. Similarly, studies using VR or AR focus on enhancing conceptual understanding through visualisation, but do not require students to apply engineering principles or mathematical reasoning to solve authentic problems.

The prevalence of superficial integration in nearly two-thirds of the reviewed literature indicates that, whilst the STEM label is widely adopted, its actual implementation often falls short of the interdisciplinary ideal promoted in policy documents. This gap between aspiration and practice is a central manifestation of the theoretical fragmentation that this review seeks to map.

### *Interdisciplinary integration*

Conversely, only 36% of studies (n = 21) achieved genuine interdisciplinary integration, in which the four STEM components were explicitly synthesised. These studies typically employ a PjBL or PBL framework that requires students to engage in engineering design processes, apply mathematical reasoning to optimise solutions, and use technology as a mediating tool. Exemplary studies in this category include Portillo-Blanco et al. (2025), in which trainee teachers designed and built an autonomous car, a project requiring scientific understanding, engineering design, mathematical modelling, and technological implementation. Similarly, Martawijaya et al. (2023) integrated ethno-STEM principles with PjBL, requiring students to apply physics concepts to solve local community problems whilst documenting their engineering design processes. Another study has been conducted by Oviedo-berrocal et al. (2026) examined how STEM is integrated with the cultural dimensions of indigenous and traditional knowledge. The results indicate a growing trend toward contextualized and integrative STEM instruction that emphasizes the cultural dimensions of indigenous and traditional knowledge. These findings demonstrate its potential as a basis for future research on the integration of traditional knowledge in diverse intercultural contexts in STEM education.

What distinguishes these interdisciplinary studies is not merely the use of technology or projects, but the explicit articulation of how each STEM domain contributes to and interacts with the others. In these studies, students do not merely learn physics; they learn to think like engineers, using technology as a tool for inquiry, and applying mathematical reasoning to optimise solutions

### *The fragmentation-integration paradox*

The findings in this section reveal a critical paradox: whilst STEM is founded on the principle of interdisciplinary integration, the majority of the studies reviewed (60%) implement integration only superficially. Furthermore, there is no clear relationship between how STEM is conceptualised and the depth of integration achieved. Studies conceptualising STEM as technology-focused integration are not necessarily superficial, and studies conceptualising STEM as pedagogy are not necessarily interdisciplinary. This inconsistency further underscores the need for a more coherent theoretical framework that can guide both research and practice.

## Pedagogical approaches in STEM-based physics education

Having mapped the conceptual fragmentation and variations in the depth of integration, this section examines the pedagogical approaches used in the studies reviewed. Rather than merely cataloguing which models appear most frequently, the findings of this article attempt to analyse why certain approaches dominate and what this reveals about the field's underlying assumptions regarding how STEM integration should be implemented.

### *The dominance of project-based learning and problem-based learning*

Project-Based Learning (PjBL) and Problem-Based Learning (PBL) emerged as the most frequently used pedagogical models, appearing in 9 of the 57 studies reviewed (16%). The dominance of these two approaches is no coincidence; PjBL and PBL share fundamental characteristics with the STEM framework. Both are student-centred, inquiry-based, and oriented towards authentic real-world challenges, characteristics that align with the interdisciplinary goals of STEM education. Furthermore, both models naturally accommodate the engineering design process through an iterative cycle of problem definition, solution design, testing, and refinement.

However, the prevalence of PjBL and PBL also raises an important question. These pedagogical models predate the contemporary STEM movement by a considerable margin (Barrows & Tamblyn, 1980). The fact that both now appear primarily under the 'STEM' label suggests that STEM integration may, in practice, be less of a pedagogical innovation and more of a reconceptualisation or rebranding of established practices. This observation is not intended to diminish the value of PjBL or PBL, both of which are strongly supported by evidence, but to highlight that the conceptual contribution of 'STEM' as a framework remains insufficiently theorised in much of the literature.

### *Technology-based approaches*

In addition to PjBL and PBL, technology-based approaches represent the second major category of pedagogical innovations, encompassing a variety of tools, including Arduino microcontrollers (n = 6), virtual and augmented reality (n = 5), simulation software (n = 4), and computational thinking platforms (n = 3). These studies reflect a growing recognition that technology is not merely a delivery mechanism, but can function as a cognitive tool that shapes the way students engage with physics concepts.

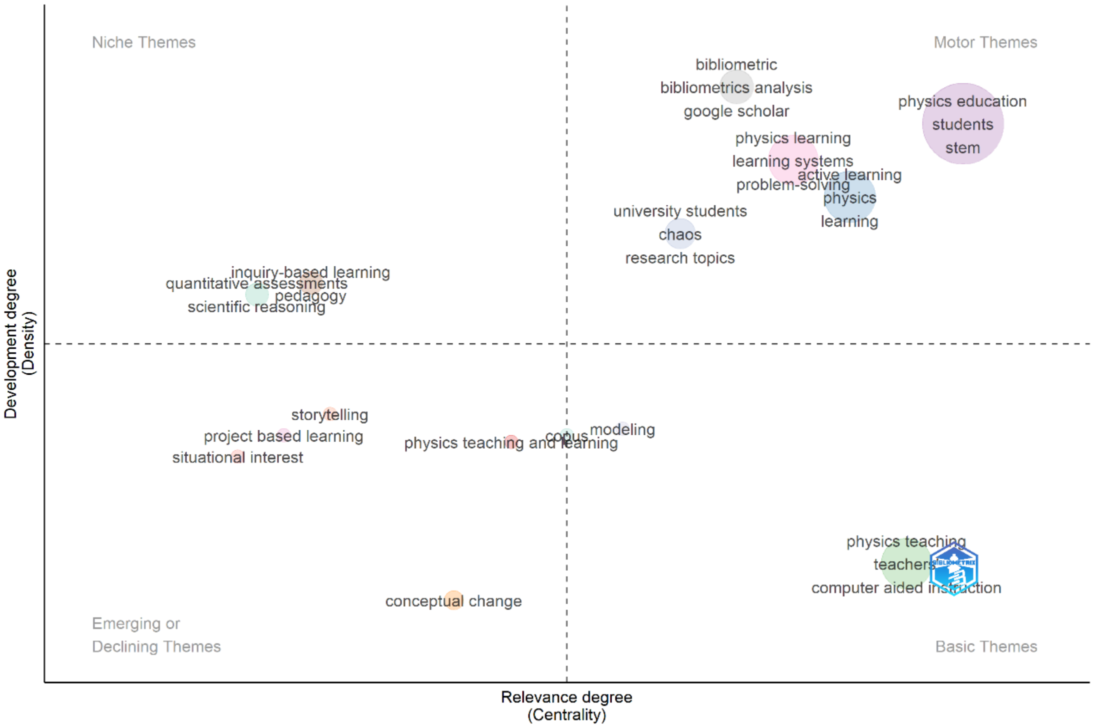
Paradoxically, although technology is one of the four components of STEM, its integration in the reviewed literature often occurs in ways that fail to fully utilise its potential to connect the other three domains. In many studies focusing on technology, the ‘science’ component is limited to established physics principles, the ‘engineering’ component is reduced to assembling basic systems, and the ‘mathematics’ component is confined to basic data representation rather than mathematical modelling or optimisation. This pattern reinforces previous findings that superficial integration remains the norm and is insufficiently developed to address authentic interdisciplinary problems.

### Research gap: From descriptive trends to theoretical and methodological challenge

The results of the bibliometric analysis regarding research gaps and future research can be seen in **Figure 5** below:

**Figure 5**

*Thematic map of STEM physics education research*



Based on the thematic map in Figure 5, one of the themes highlighted in STEM research in physics education is computer-aided instruction, which relates to the use of digital learning technologies to create interactive and experiential physics learning environments. Various technologies have been adapted; Virtual Reality (VR), Augmented Reality (AR), and Artificial Intelligence (AI) have been extensively developed in STEM research in physics education (Aguilar-Mejía & Tejeda, 2020; Poddar et al., 2024; Sirnoorkar et al., 2024). Nevertheless, the application of STEM-based technologies in physics education remains limited, largely due to teachers’ insufficient competence in adapting these technologies for instructional purposes (Margot & Kettler, 2019). This poses a challenge for future research development, where the integration of technology as a key aspect of STEM must be continuously enhanced. This can be achieved by providing systematic and sustained professional development for teachers, thereby enabling the implementation of the STEM approach to be more effective. Research on STEM in physics education highlights several key trends and potential directions for future research (see **Figure 5**)

### *Gap 1: conceptual gap, stem as undefined*

The most fundamental gap identified in this review is the lack of a clear definition. This conceptual gap has practical consequences, as the absence of definitional clarity makes it difficult to determine whether variations in findings reflect differences in effectiveness or merely differences in how STEM is operationalised.

Future research must prioritise conceptual clarity. This does not imply the need for a single, universal definition of STEM integration. Such an aim is neither feasible nor desirable given the diversity found within educational contexts. However, researchers must explicitly state how they define STEM integration in their studies, which components are emphasised, and how these components interact. Such transparency will enable more meaningful comparisons between studies and facilitate the development of a cumulative and theoretically coherent body of knowledge

### *Gap 2: depth gap: superficial integration vs. interdisciplinary*

The finding that 60% of studies achieve only superficial integration represents a critical gap. Although many studies claim to implement STEM education, the actual depth of integration often falls short of the interdisciplinary ideal underpinning the concept of STEM. This gap indicates that the field has not yet developed robust and replicable strategies to achieve genuine integration of the four domains.

Future research must move beyond simply demonstrating that STEM approaches are effective, and instead investigate how, why, and under what conditions deeper integration can be achieved in physics learning contexts. This requires a methodological shift towards design-based research, longitudinal studies, and in-depth analysis of students' learning processes. Furthermore, researchers must explicitly document the engineering design processes and mathematical modelling activities that occur during learning, as these elements remain underrepresented in the existing literature.

### *Gap 3: The teacher gap, professional development and tpack*

The thematic map places 'teachers' and 'computer-assisted learning' in the Basic Themes quadrant, indicating high relevance but a low level of development. This finding aligns with observations, which indicate that none of the reviewed studies focused exclusively on teachers as research subjects, despite the widely recognised importance of teacher competence for the successful implementation of STEM.

Future research should investigate how physics teachers develop the knowledge and skills required to design and implement integrated STEM instruction. Specifically, studies should explore teachers' Technological Pedagogical Content Knowledge (TPACK) within the STEM context, examining how teachers learn to integrate the four STEM domains in a conceptually coherent and pedagogically meaningful manner. Professional development programmes must be rigorously designed, implemented, and evaluated to identify best practices in preparing teachers to address the fragmentation issues identified in this review.

### *Gap 4: Methodological gap, moving beyond case studies and short-term interventions*

The fourth gap relates to the methodological approaches that dominate this field. The majority of the studies reviewed employed short-term interventions, ranging from a few days to one academic term, with limited follow-up. Whilst such studies provide valuable preliminary evidence, they cannot adequately address questions related to long-term retention, transfer of learning, or sustained changes in students' attitudes towards STEM.

Future research should employ longitudinal designs to examine how students' understanding of integrated STEM physics develops over time. A mixed-methods approach combining quantitative measures of learning outcomes with qualitative analysis of students' reasoning, engagement, and identity formation will provide a more comprehensive understanding of the mechanisms through which STEM integration influences learning. Furthermore, replication studies, which are rarely conducted in the current literature, are crucial for establishing the consistency of findings across different contexts, student populations, and implementation conditions.

### *Summary: An agenda for coherence*

The four gaps identified above, conceptual, depth, teacher, and methodological, are interrelated. Without conceptual clarity, it is difficult to design deep integration. Without deep integration, teachers lack models to emulate in their professional development. Without robust methodology, the field cannot generate the evidence required to refine its theoretical framework. To address these gaps, a coordinated effort is required to move beyond descriptive accounts of 'what works' towards theory-driven and methodologically rigorous investigations into how STEM integration can be realised in physics education in a conceptually coherent and practically sustainable manner.

### Implications and directions for research development

Based on the synthesis of findings, several important implications emerge for the development of research and practice in STEM-based physics education. Firstly, STEM integration needs to be developed through a more coherent conceptual framework, encompassing explicit connections between the components of science, technology, engineering, and mathematics. Secondly, the implementation of learning models such as blended and digital STEM learning needs to be expanded to strengthen learners' access to and technological literacy across various levels of education. Thirdly, the findings emphasise the importance of authentic assessment based on Higher-Order Thinking Skills (HOTS) and STEM literacy to comprehensively measure higher-order thinking skills. Fourthly, future research is advised to examine the long-term effectiveness of STEM integration on knowledge transfer and scientific literacy using longitudinal and mixed-method approaches. Overall, the direction of STEM research in physics education indicates a shift from predominantly instructional innovation towards deeper pedagogical and conceptual integration, in which STEM functions not only as a teaching approach but also as a broader epistemological framework for constructing scientific understanding aligned with the demands of the 21st century.

### Limitations

This systematic review has several limitations that should be acknowledged when interpreting its findings, they are:

- First, the search was limited to a single database, Scopus, and included only Open Access articles. This selection criterion, whilst ensuring full-text availability, may have excluded relevant studies published in other databases such as Web of Science, ERIC, or Google Scholar, as well as non-open-access articles that could provide additional insights into STEM integration in physics education.
- Second, the search was restricted to the "Social Sciences" (SOCI) subject area to maintain relevance to pedagogical aspects. Consequently, STEM-integrated physics education studies published in pure physics journals (PHYS category) were not included in this review. Given that physics education research is inherently interdisciplinary, this delimitation may have resulted in the omission of studies that focus more on content development than instructional design.
- Third, this review analysed only journal articles published in English. Conference proceedings, books, book chapters, and non-English publications were excluded. This may introduce language and publication type bias, as emerging findings or practices from non-English-speaking contexts may not be fully represented.
- Fourth, the conceptual categorisation of STEM integration into pedagogical models and technology or tool integration was based on the authors' interpretation of the 'Type of STEM Integration' column in each article. Although efforts were made to ensure consistency through iterative coding and discussion amongst the research team, the subjective nature of this coding process remains an inherent limitation of qualitative synthesis approaches.
- Fifth, as a systematic literature review, this study focuses on analysing publication trends, conceptualisations, and methodological patterns rather than measuring the effectiveness of STEM implementation. Therefore, the findings should not be generalised as indicators of STEM's pedagogical effectiveness in physics education. Studies included in this review employed diverse research designs, outcome measures, and contextual factors, making direct comparisons of effectiveness beyond the scope of the present analysis.

Finally, the temporal scope of this review (2016–2025) covers a decade of research but may not fully reflect the most recent developments published after the search period. Given the rapid evolution of technology-enhanced STEM education, particularly with the emergence of artificial intelligence and learning analytics, future reviews should consider extending the timeframe to include more recent innovations.

Despite these limitations, this review provides a comprehensive and systematic mapping of how STEM integration has been conceptualised and operationalised in physics education research over the past decade. The findings offer a foundation for addressing the conceptual fragmentation identified in the literature and for guiding future research towards more coherent theoretical, methodological, and practical approaches.

## CONCLUSION

This review synthesises trends in STEM research in physics education over the last 10 years (2016–2025). The analysis indicates a significant increase in publications after 2018, peaking in 2023 and subsequently stabilising in 2024–2025. Indonesia, Malaysia, and the United States are the main contributors, reflecting the strategic role of the United States as an early centre for the development of the STEM framework, as well as Southeast Asian regional policies supporting curriculum reform and the development of teacher competencies in STEM. These studies demonstrate variations in the integration of methods, models, approaches, and teaching materials in STEM-based physics learning. The most dominant pedagogical models are STEM Problem-Based Learning and STEM Project-Based Learning, followed by technology-based approaches such as STEM Digital Learning (Arduino), the Flipped Classroom, Lightboard, and Python Coding. Gamification approaches have emerged as a new trend that has been shown to enhance student engagement, motivation, and a sense of ownership over the learning process.

The educational levels covered by STEM research are predominantly those of upper secondary school pupils and university students. This is because pupils and students are considered to have attained sufficient cognitive and conceptual understanding to grasp the relationships between science, technology, engineering, and mathematics within the framework of physics. Overall, STEM research in physics education focuses on technological innovation and engineering solutions that link physics theory with practical applications. The findings of this synthesis yield important implications for the development of research and STEM practice. In practical terms, it is recommended that STEM integration be developed within a more coherent conceptual framework. Future research is advised to examine the effectiveness of STEM domain integration on knowledge transfer and scientific literacy through longitudinal and mixed-method approaches in order to develop a more comprehensive and sustainable understanding

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### Ethical statement

This study was a systematic literature review and did not involve human or animal participants. Therefore, ethics approval and informed consent were not required.

### Competing interests

The authors declare that they have no competing interests.

### Author contributions

Rahmania Amanah Putri contributed to the research concept and design, collection and/or assembly of data, data analysis and interpretation, writing the article, and critical revision of the article. Heru Kuswanto contributed to the research concept and design, data analysis and interpretation and final approval of the article. Rahmi contributed to the collection and/or assembly of data, data analysis and interpretation, writing the article, and critical revision of the article. I'liyatunnisa' contributed to the research concept and design, writing the article, and final approval of the article. Meza Saputri contributed to the collection and/or assembly of data, data analysis and interpretation, and writing the article. Muh. Syahrul Padli contributed to the collection and/or assembly of data and wrote the article. Tugirin contributed to the collection and/or assembly of data, data analysis and interpretation, and writing the article. Masak contributed to the collection and/or assembly of data, data analysis and interpretation, and writing the article. Muhammad Najih Hamdi contributed to the research concept and design, collection and/or assembly of data, and writing the article. Nurul Aziza contributed to the collection and/or assembly of data, data analysis and interpretation, and writing the article. All authors read and approved the final manuscript.

### Data availability

The data supporting the findings of this systematic literature review were obtained from the publicly available database Scopus. The search strategy, including search strings and eligibility criteria, is described in the methodology section to ensure transparency and reproducibility. All relevant data are included within the article and its references.

## AI disclosure

The authors used artificial intelligence (AI) DeepSeek tools to support language editing and text refinement. All content was critically reviewed, revised, and approved by the authors, who take full responsibility for the final version of the manuscript.

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## APPENDIX

**Table 1**

*Overview of included studies in the systematic literature review (n = 57)*

| ID | Author(s) & Year | Region/Country | Type of STEM Integration | STEM Component | Education Level |
|---|---|---|---|---|---|
| S01 | (Parno et al., 2020) | Indonesia | **Pedagogical Model:** PBL-STEM | S, T, E, M (all four) | Secondary School |
| S02 | (Rosidin et al., 2019) | Indonesia | **Pedagogical Model:** STEM learning model with HOTS-based assessment | S, T, E, M (all four) | Secondary School |
| S03 | (Rosanna E. Guadagno et al., 2021) | USA | **Technology/Tool:** Modelling and simulation programme (STEPP) | S, T, E | High School |
| S04 | (Parcerisas et al., 2022) | Spain | **Authentic Research/Tool:** CERN Timepix detectors | S, T | High School |
| S05 | (Sydykova & Zh.A, 2024) | Kazakhstan | **Pedagogical Model**: Project-Based Learning (PjBL) with STEM | S, T, E, M (all four) | Secondary School |
| S06 | (Pickup & Roch, 2025) | UK | **Technology/Tool**: Design of an Arduino-based measurement tool | S, T, E | High School |
| S07 | (Osvaldo Aquines Gutiérrez et al., | Mexico | **Technology/Tool**: Web-based simulation (Newtondreams) | S,T | Higher Education |

| ID | Author(s) & Year | Region/Country | Type of STEM Integration | STEM Component | Education Level |
|---|---|---|---|---|---|
| | 2022) | | | | |
| S08 | (Bodensiek et al., 2019) | Germany | **Technology**: Augmented Reality (AR) smart glasses | S, T | Higher Education |
| S09 | (Portillo-Blanco et al., 2025) | Spain | **Pedagogical Model**: iSTEM TLS (Project-based learning with robotics) | S, T, E, M (all four) | Higher Education |
| S10 | (Bufasi et al., 2022) | Albania / Kuwait / Latvia | **Technology/Tool**: Computational thinking with VPython programming | S, T, M | High School |
| S11 | (Rahmayani et al., 2024) | Indonesia | **Technology/Tool**: E-book with AR technology integrated with a STEM approach | S, T, E | High School |
| S12 | (Martinez-Borreguero et al., 2022) | Spain | **Technology/Tool**: Hyper-realistic simulations for teaching optics | S, T | Higher Education (pre-service teacher) |
| S13 | (Martyniuk et al., 2021) | Ukraine | **Technology/Tool**: Blended learning with digital laboratories and BYOD | S, T, M | Secondary School |
| S14 | (Matos & Zannin, 2021) | Brazil | **Technology/Tool**: Educational robotics (Arduino) with a mobile app for physics experiments | S, T, E | Secondary School |
| S15 | (González-Peña et al., 2021) | Mexico | **Pedagogical Model**: Inquiry-based learning with home experiments | S, T, M | Higher Education |
| S16 | (Solomon et al., 2022) | USA | **Pedagogical Model**: Embodied learning through dance/choreography | S, T | High School (non-formal school) |
| S17 | (Muñoz-Losa & Marcos-Merino, 2024) | Spain | **Pedagogical Model**: STEM practice with hands-on activities (simple machines) | S, T, E, M (all four) | Higher Education (Pre-service teachers) |
| S18 | (Werth et al., 2023) | USA | **Pedagogical Model**: CURE (Course-based Undergraduate Research Experience) | S, T | Higher Education (Undergraduate) |
| S19 | (Verawati et al., 2022) | Indonesia | **Technology/Tool**: Virtual simulation integrated with LMS | S, T | Higher Education (STEM Students) |

| ID | Author(s) & Year | Region/Country | Type of STEM Integration | STEM Component | Education Level |
|---|---|---|---|---|---|
| S20 | (Pattayev et al., 2024) | Kazakhstan | **Pedagogical Model**: STEAM projects (solar energy, photovoltaic systems) | S, T, E, M (all four) | Higher Education (Undergraduate) |
| S21 | (Herlina et al., 2025) | Indonesia | **Technology/Tool**: E-worksheet with the ExPRession learning model | S, T, M | High School (Physics Students) |
| S22 | (Kapon et al., 2021) | Israel | **Pedagogical Model**: EMBI (Engineering Maker-Based Inquiry) | S, T, E | High School (Advanced Physics) |
| S23 | (Çoban & Erol, 2025) | Turkey | **Technology/Tool**: Arduino-based STEM materials for mechanics experiments | S, T, E, M (all four) | Higher Education (Pre-service teachers) |
| S24 | (Campos et al., 2022) | Mexico | **Technology/Tool**: VR with Gravity Sketch for 3D vector learning | S, T, M | Higher Education (Engineering students) |
| S25 | (Yusuf et al., 2018) | Indonesia | **Pedagogical Model**: E-learning with a STEM approach | S, T | Higher Education (Physics education students) |
| S26 | (Hakim et al., 2023) | Indonesia | **Technology/Tool**: STEM-based physics teaching materials (EDP model) | S, T, E, M (all four) | Secondary School |
| S27 | (Nor Farahwahidah Abd Rahman et al., 2021) | Malaysia | **Pedagogical Model**: Informal science learning with STEM activities (Mini Titanic) | S, T, E, M (all four) | Secondary School |
| S28 | (Oprea et al., 2023) | Romania | **Technology/Tool**: Arduino, sensors, Data Streamer for physics experiments | S, T, E, M (all four) | Secondary School |
| S29 | (Dominguez et al., 2024) | Mexico | **Pedagogical Model**: Modelling instruction in an integrated physics-maths course | S, M | Higher Education (Engineering students) |
| S30 | (Wolke et al., 2024) | Germany | **Pedagogical Model**: STEAM education (physics and art collaboration) | S, T, A | Secondary School |
| S31 | (Freese et al., 2023) | Germany | **Technology/Tool**: Augmented Reality (AR) experiments | S, T | Higher Education (Teacher training) |

| ID | Author(s) & Year | Region/Country | Type of STEM Integration | STEM Component | Education Level |
|---|---|---|---|---|---|
| S32 | (Kuzmenko et al., 2023) | Ukraine | **Technology/Tool**: Ontology-oriented information systems | S, T, M | Higher Education |
| S33 | (Asrizal et al., 2022) | Indonesia | **Pedagogical Model**: STEM-integrated e-teaching material | S, T, E, M (all four) | Secondary School |
| S34 | (Coello et al., 2024) | Ecuador | **Pedagogical Model**: Integration of STEM, TRIZ and Industry 4.0 | S, T, E, M (all four) | Higher Education |
| S35 | (Samsudin et al., 2020) | Malaysia | **Pedagogical Model**: STEM PjBL (pulley system project) | S, T, E, M (all four) | Secondary School |
| S36 | (Felipe Miguel Álvarez-Siordia et al., 2025) | Mexico | **Technology/Tool**: PhET simulators | S, T | Higher Education |
| S37 | (Baptista et al., 2020) | Portugal | **Pedagogical Model**: STEM activity with reverse engineering (sound topic) | S, T, E, M (all four) | Secondary School |
| S38 | (Khalil et al., 2023) | UAE | **Pedagogical Model**: STEM-based curriculum (IB curriculum) | S, T, E, M (all four) | Secondary School |
| S39 | (Asrizal et al., 2023) | Indonesia | **Technology/Tool**: STEM-integrated digital teaching material | S, T, E, M (all four) | Secondary school |
| S40 | (Asrizal et al., 2024) | Indonesia | **Technology/Tool**: STEM-Smart E-Module (smartphone-based) | S, T, E, M (all four) | Secondary School |
| S41 | (Chen et al., 2025) | USA | **Technology/Tool**: 3D printing for circuit templates | S, T, E | Secondary School |
| S42 | (Martins & Baptista, 2024) | Portugal | **Pedagogical Model**: iSTEAM TPD (reverse engineering activity) | S, T, E, A | Higher Education (Teacher training) |
| S43 | (Lane et al., 2023) | USA | **Pedagogical Model**: CT integration with Python programming | S, T, M | Higher Education (Teacher training) |
| S44 | (Addido et al., 2023) | USA | **Technology/Tool**: (Robotics-based instruction as a tool for teaching physics). | S, T, E, M (all four) | High School |
| S45 | (Martawijaya et al., 2023) | Indonesia | **Interdisciplinary with an Ethnoscience approach**. Integrating | S, T, E, M (all four) | High School |

| ID | Author(s) & Year | Region/Country | Type of STEM Integration | STEM Component | Education Level |
|---|---|---|---|---|---|
| | | | local wisdom (the culture around Lake Tempe) with STEM in a PjBL model. | | |
| S46 | (Samsudin et al., 2020) | Malaysia | **Pedagogical Model**: (STEM-PjBL) to enhance students' self-efficacy in mechanical physics. | S, T, E, M (all four) | High School |
| S47 | (Sulaiman et al., 2024) | Malaysia | **Technology/Tool**: (iSTEM-PjBL) in classical physics learning modules. | S, T, E, M (all four) | Secondary School |
| S48 | (Sagala et al., 2019) | Indonesia | **Technology/Tool**: (ESciT integrated with STEM) to enhance understanding of physics concepts. | S, T, E, M (all four) | High School |
| S49 | (Sulaiman et al., 2023) | Korea and Malaysia | **Technology/Tool**: Integrated physics learning module (iSTEM-PjBL) | S, T, E, M (all four) | High School |
| S50 | (Supian et al., 2023) | Malaysia | **Technology/Tool**: (STEM module) embedded with technology for the topic of solar energy. | S, T, E, M (all four) | Higher Education (diploma students) |
| S51 | (Ardianti et al., 2020) | Indonesia | **Pedagogical Model**: (STEM) integrated into a blended learning model. | S, T, E, M (all four) | Secondary School |
| S52 | (Suhartono et al., 2023) | Indonesia | **Transdisciplinary**. Integration of STEM with the Among philosophy (local wisdom) in a simple laser-making project. | S, T, E, M (all four) | Higher education (Physics Education students) |
| S53 | (Çoban et al., 2023) | Turkey | **Technology/Tool**: Using Arduino as a technological tool to conduct physics experiments. | S, T, E, M (all four) | Secondary School / Higher Education |
| S54 | (HAIDONG CHEN et al., 2025) | China | **Technology/Tool**: integrating martial arts (Bajiquan) and technology-based motion analysis. | S, T, E, M (all four) | Higher Education |
| S55 | (Atakan Çoban | Turkey | **Technology/Tool**: | S, T, E, M | High School |

| ID | Author(s) & Year | Region/Country | Type of STEM Integration | STEM Component | Education Level |
|---|---|---|---|---|---|
| | & Niyazi Çoban, 2022) | | Using Arduino and sensors as technological tools to conduct physics experiments. | (all four) | |
| S56 | (Odden et al., 2023) | Norway | **Technology/Tool**: Using computational essays as a tool to integrate programming with scientific writing in physics. | S, T, E, M (all four) | Higher Education (Undergraduate) |
| S57 | (Euler et al., 2020) | Sweden | **Technology/Tool**: Using Algodoo software (less-constrained DLE) for the exploration of physics concepts with responsive teacher guidance. | S, T, E, M (all four) | Higher Education (Pre-service teachers) |