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Scientist-School STEM partnerships in K-12 education: A comprehensive systematic review

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ABSTRACT

Scientist-school STEM partnerships have been globally recognised as powerful pedagogical strategies for enhancing STEM education by connecting classroom instruction with real-world scientific practices. Despite growing interest in these collaborations, understanding of their outcomes, challenges, and practices remains limited. This systematic review examines studies published between 2016 and 2025, drawing on Web of Science, Scopus, and ERIC databases and following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. A total of 45 relevant studies across 12 countries were identified and analysed, generating three key themes: outcomes of scientist-school STEM partnerships, challenges in implementation, and best practices for sustainable partnerships. The findings reveal that these partnerships provide significant benefits for teachers, students, scientists, and institutions. However, key challenges include time constraints, curriculum integration, limited resources, inadequate administrative support, scientific language barriers, insufficient funding, communication and technology issues, and gaps in content knowledge. Best practices include providing authentic science experiences, aligning partnerships with the curriculum, ensuring adequate support and funding, integrating technology and digital tools, establishing clear reform goals, promoting co-teaching and co-design, contextualising learning for students, and expanding STEM partnerships to include humanities and social sciences. This review contributes to global STEM education discourse by synthesising decade-long empirical evidence across 12 countries and establishing an integrative framework for understanding and sustaining scientist-school STEM partnerships. The findings offer valuable insights for policymakers, educators, researchers, and practitioners seeking to develop longitudinal, cross-national, and interdisciplinary partnership models that promote digital innovation, equitable collaboration, contextualised STEM practices, and real-world impact in K-12 science education.

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Introduction

In recent decades, there has been an escalating demand to enhance the quality of Science, Technology, Engineering, and Mathematics (STEM) education that extends beyond the boundaries of the traditional classroom due to the mounting complexity of worldwide challenges such as climate change, health predicaments, and technological advancements. Partnerships involving scientists from industry or academia have garnered significant, wide-reaching attention across various educational contexts, particularly K-12 schools, and have endeavoured to bridge the gap between traditional formal STEM classroom instruction and real-world scientific practice. Collaboration between scientists and schools has emerged as one effective strategy to enrich STEM learning experiences by bridging formal learning with authentic scientific practice (Bopardikar et al., 2023; Houseal et al., 2014; Taylor et al., 2022; Yahya et al., 2026).

A mounting body of literature advocates for greater opportunities for K-12 students to engage with science role models as experts and for teachers and students to collaborate with scientists (Kang & González-Howard, 2022; Yahya et al., 2025a). In response to this call to action, scientists frequently incorporate plans into their research proposals that outline commitments to visit educational institutions or host students in their laboratories, aiming to share their research methodologies and practices. "Scientist-school STEM partnerships" refer to collaboration between two parties, scientists and schools, including teachers and/or students, through partnerships to strengthen STEM learning in schools. These partnerships are often referred to as Scientist-Teacher-Student Partnerships (STSP) (Bopardikar et al., 2023; Çavaş et al., 2021; Saat et al., 2023; Westbrook et al., 2023), scientist-teacher partnership (Atias et al., 2023b; Morris et al., 2021), or a scientist-student partnerships (SSP) as in studies conducted by Hsu (2018) and Westbrook et al. (2023).

Generally, collaborations between scientists, teachers, and students in schools embrace classroom visits, co-teaching, mentoring, and collaborative curriculum design. These efforts and initiatives offer valuable opportunities for scientists to team up in contributing their expertise and knowledge to make STEM learning more engaging and not solely guided by textbooks. These partnerships are established on the principle that direct engagement with scientists can significantly enhance students' conceptual understanding, foster inquiry skills, provide hands-on learning opportunities, and encourage interest in STEM careers (Abramowitz et al., 2024a; Fadzil et al., 2019; Morris et al., 2021; Ogodo et al., 2023; Yawson et al., 2016). Through the partnership, students and teachers gain access to the latest scientific knowledge, research instruments, and real-world problem-solving practices (Vamvakas et al., 2023). Teachers also gain opportunities for professional development, strengthening their pedagogical content knowledge, boosting teachers' confidence in delivering STEM content, enriching classroom engagement, and improving teaching effectiveness with support and mentoring from scientists in implementing effective teaching strategies and using innovative methodologies (Basche et al., 2016; Çavaş et al., 2021; Maina et al., 2021; Saat et al., 2021). Concurrently, scientists get the best platform to contribute to developing and conveying knowledge based on the latest research (Saat et al., 2023; Yahya et al., 2025b). Therefore, this study highlights the critical value of partnerships among students, teachers, and scientists, emphasizing best practices that can be built upon from past studies.

Despite increasing scholarly attention, most existing studies on scientist–school STEM partnerships are confined to localised case studies or single-nation initiatives, often focusing on isolated outcomes or short-term impacts. Previous literature has yet to provide a systematic, cross-national synthesis that maps the breadth of partnership models, pedagogical outcomes, and implementation challenges across different educational contexts. As a result, there remains a critical gap in understanding how such partnerships operate, evolve and sustain themselves within diverse global STEM education systems (Abramowitz et al., 2024b; Çavaş et al., 2021; Ufnar & Shepherd, 2020). This review addresses that gap by providing a comprehensive global synthesis of empirical evidence published between 2016 and 2025, encompassing 45 studies from 12 countries. By systematically comparing findings across different educational and cultural contexts, this study contributes a novel integrative framework that links pedagogical outcomes, systemic challenges, and best practices for sustainable scientist-school STEM partnerships. The review's objectives are directly aligned with this contribution to illuminate global patterns, identify contextual variations, and inform policy and practice for future cross-sector collaborations in STEM education.

Literature Review

Scientist-School STEM Partnerships

Scientist-school STEM partnerships represent collaborative arrangements between scientists, teachers, and students designed to connect school science with authentic scientific inquiry. Theoretically, this study is grounded in Communities of Practice (Pyrko et al., 2019; Wenger, 1998). This partnership promote mutual engagement and shared meaning-making between formal and professional learning communities (Perron, 2021; Witovisk et al., 2020). Over the past decade, scientist–school partnerships have diversified in structure from outreach activities and citizen-science programs to sustained professional development initiatives such as the Scientist in the Classroom Partnership (SCP) in the United States and the Scientist-Teacher-Student Partnership (STSP) in Malaysia and Türkiye (Ufnar & Shepherd, 2020; Saat et al., 2023; Çavaş et al., 2021). These collaborations operationalise experiential and sociocultural learning by positioning scientists as co-educators, teachers as knowledge mediators, and students as inquiry participants who experience the epistemic practices of science (Atias et al., 2023b; Bopardikar et al., 2023). The scientist–school STEM partnerships aim to enhance student engagement and effective trans-disciplinary learning in STEM by embedding authentic science experiences that align with classroom content (Çavaş et al., 2021).

Outcomes of Scientist–School STEM Partnerships

Empirical evidence demonstrates that scientist-school partnerships generate multidimensional outcomes across teachers, students, scientists and institutions. Teachers benefit through enhanced pedagogical content knowledge (PCK), improved inquiry-based instructional practices, and greater confidence in facilitating STEM learning (Basche et al., 2016; Morris et al., 2021). Partnerships strengthen teachers' professional networks and offer access to current research tools, thereby fostering sustained professional growth (Maina et al., 2021; Dai, 2023). Students gain authentic exposure to real-world science, resulting in heightened engagement, motivation, and scientific literacy (Taylor et al., 2022; Westbrook et al., 2023). Such authentic mentorships help cultivate positive attitudes toward scientists, strengthen science identity, and encourage STEM career aspirations (Childers & Jones, 2017; Fadzil et al., 2019). Scientists, in turn, develop pedagogical communication skills and public engagement competencies (Olitsky et al., 2020), while institutions benefit from reinforced university-school linkages that enrich curricula and community engagement (Abramowitz et al., 2024b). Collectively, these outcomes position scientist–school partnerships as catalysts for professional learning, student empowerment, and systemic improvement in STEM education.

Challenges in Implementing Partnerships

Despite their benefits, scientist–school partnerships face numerous systemic, logistical and cultural challenges. Time constraints are among the most cited barriers, limiting both teachers' capacity for extended collaboration and scientists' sustained engagement (Aslam et al., 2018; Ufnar et al., 2018). Institutional issues such as misaligned objectives, insufficient administrative or financial support, and inconsistent policy recognition hinder program sustainability (Ogodo et al., 2023; Çavaş et al., 2021). Communication difficulties, stemming from disciplinary jargon and divergent epistemic norms, further complicate co-teaching and curriculum co-design (Hsu, 2018; Peterson et al., 2024). Additionally, the need for curricular alignment and assessment coherence presents an ongoing tension between authenticity and accountability (Bopardikar et al., 2023; Saat et al., 2023). Many partnerships remain localised or short-term, restricting generalisations and policy impacts (Vamvakas et al., 2023). Overcoming these challenges requires clear governance frameworks, long-term funding, and institutionalised collaborative mechanisms that embed partnerships into school and university systems (Mansour & El-Deghaidy, 2020; Ufnar & Shepherd, 2020).

Best Practices and Sustainable Models

Synthesised findings reveal a set of interrelated design principles for sustaining effective partnerships. Authentic, curriculum-aligned experiences that integrate inquiry within national standards enhance teacher adoption and curricular coherence (Atias et al., 2023b; Ismail et al., 2024). Co-design and co-teaching structures, which distribute expertise between teachers and scientists, foster shared ownership and contextual relevance (Abramowitz et al., 2024a; Morris et al., 2021). Sustainability correlates strongly with institutional and policy support, including funding continuity, administrative recognition, and coordinated leadership (Çavaş et al., 2021; Ufnar & Shepherd, 2020). The purposeful use of digital technologies such as virtual mentoring and remote data collection has expanded accessibility and allowed cross-regional collaboration (Ng & Fergusson, 2019; Vamvakas et al., 2023). Together, these practices suggest that sustainable scientist–school partnerships arise from the synergistic alignment of curriculum, institutional support, and cultural context.

Rationale for the Review and Research Questions

The United States has dominated research on scientist and school partnerships (Abramowitz et al., 2024a), as exemplified by a study by Ufnar and Shepherd (2020), which has sustained this partnership for 20 years and is funded by the National Science Foundation (NSF). However, very few literature review papers are available to explore various aspects of the impacts of the implementation, challenges and best practices for the sustainability successes of scientist-school partnerships in STEM education on a global scale. Note that this partnership is becoming a global initiative highlighted by efforts in numerous countries, such as Australia (Morris et al., 2021; Puslednik & Brennan, 2020; Vamvakas et al., 2023); Canada (Simms et al., 2024; Snitynsky et al., 2019; Sprowls, 2020); United Kingdom (UK) (Aslam et al., 2018); The Netherlands (Masson et al., 2016); Türkiye (Çavaş et al., 2021); Ghana (Yawson et al., 2016); China (So et al., 2021); Malaysia (Saat et al., 2023); New Zealand (Falloon, 2020); Saudi Arabia (Mansour & El-Deghaidy, 2020); Brazil (Witovisk et al., 2020) and France (Perron, 2021).

Despite their widespread implementation across various countries and educational contexts, there is a lack of a comprehensive synthesis that has systematically reviewed the full breadth of pedagogical strategies, stakeholder outcomes, and implementation challenges across scientist-school partnerships. Prior research often centers on individual case studies or localised initiatives, limiting the ability to generalise findings or inform large-scale policy and practice (Basche et al., 2016; Ufnar & Shepherd, 2019; Saat et al., 2023; Vamvakas et al., 2023). Moreover, the diversity in partnership structures, ranging from short-term scientist visits and outreach activities (Ng & Fergusson, 2019; So et al., 2021) to long-term co-teaching and curriculum co-design models (Atias et al., 2023b; Çavaş et al., 2021; Ufnar & Shepherd, 2019) necessitates a holistic analysis to map the landscape of current practices and identify key success factors (Abramowitz et al., 2024b; Simms et al., 2024). Such an analysis is vital for informing educational stakeholders, including policymakers, educators, and scientists, to design, implement, and sustain meaningful scientist-school STEM partnerships.

Ultimately, this review contributes to developing a more coherent and evidence-informed foundation for advancing STEM education through cross-sector collaboration. Beyond addressing the empirical gaps, this review holds significant importance in shaping the evolving landscape of STEM education globally. It provides one of the few comprehensive syntheses that systematically map the outcomes, challenges, and sustainable practices of scientist–school STEM partnerships across diverse cultural and policy contexts. By consolidating findings from 45 empirical studies conducted between 2016 and 2025, this review advances a global understanding of how partnerships between scientists, teachers, and students can transform traditional STEM instruction into authentic, inquiry-driven, and enjoyable science learning.

The review's integrated framework enhances theoretical understanding by positioning partnership practices within the Communities of Practice paradigm. It also provides valuable insights for policymakers and curriculum developers seeking evidence-based strategies to strengthen school-community connections. For practitioners, the synthesis offers practical guidance on effective partnership design, co-teaching models, and resource mobilization, all of which can be tailored to various educational systems. Furthermore, by identifying cross-national trends and gaps, this review establishes a research agenda for future scholars to investigate how contextual factors such as policy environments, digital innovation, and teacher professional development affect the success and sustainability of STEM partnerships.

In this regard, the review contributes to both academic scholarship and real-world application by offering a theoretically grounded, empirically supported, and globally relevant framework for enhancing STEM education through collaborative engagement. This review aims to explore scientist-school partnerships in STEM education. Thus, there are three research questions:

RQ1: What are the outcomes of scientist-school STEM partnerships?

RQ2: What are the barriers and challenges in implementing scientist-school STEM partnerships?

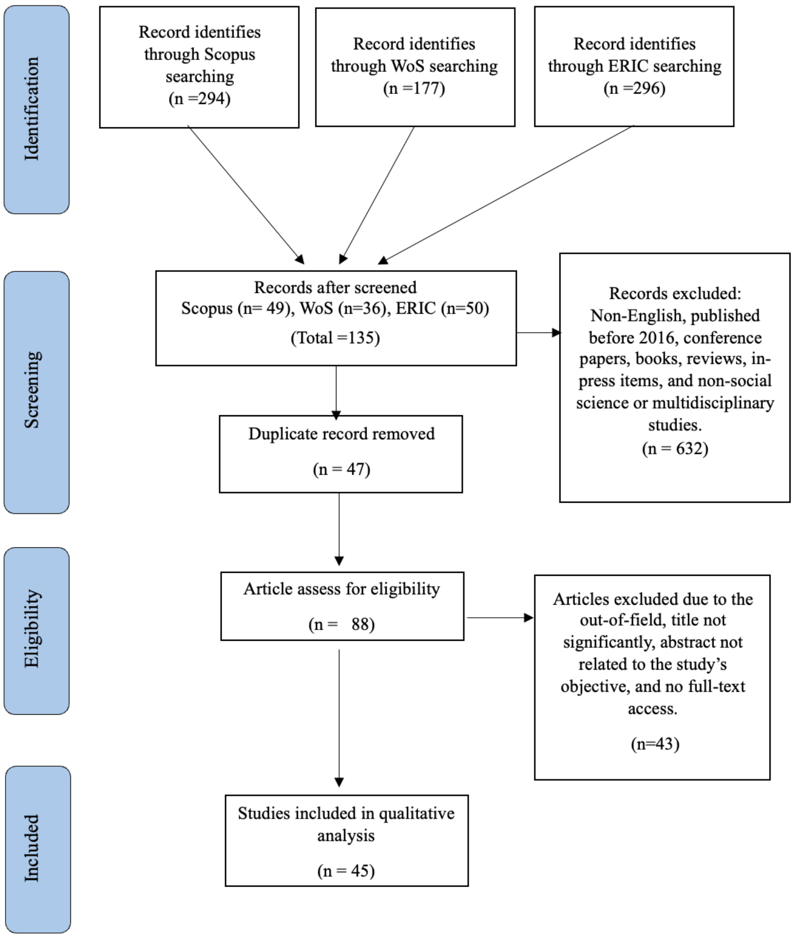
RQ3: What are the best practices for scientist-school STEM partnerships?

Methodology

We conducted a systematic review utilising the flow diagram of Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines by Moher et al. (2009) to select relevant articles (see Figure 1). PRISMA guidelines were selected for this study because of their rigorous and structured approach to conducting systematic literature reviews, which ensures transparency and replicability in handling large volumes of data. Okoli (2015) highlighted the importance of this guideline to the social sciences, which emphasized its capacity to source high-quality data from reputable publications and assist researchers in clearly articulating research restrictions using clearly defined keywords. PRISMA also provides the benefit of being a practical guideline by streamlining the review process, allowing researchers to efficiently assess the comprehensiveness of their literature search and identify pertinent studies based on the questions (Dewi & Rahayu, 2023; Dewi et al., 2021; Falah et al., 2024; Latip et al., 2024).

Figure 1

The PRISMA flow diagram utilised in the process of conducting a systematic review



There are four key steps in PRISMA to determine the suitability of studies for the researcher's needs: identification, screening, eligibility, data abstraction and analysis (Moher et al., 2009). In the identification step, researchers conduct a database search to identify all relevant studies using keywords, followed by screening, where studies are assessed against established criteria to exclude irrelevant or low-quality studies. In the eligibility phase, researchers review and evaluate the remaining studies to ensure they meet the inclusion criteria to select articles for the next stage. Regarding the final phase, researchers extract and synthesise data from the included studies in the data abstraction step, which is essential for drawing meaningful and reliable conclusions. This systematic approach was thoroughly performed, and the review was carefully conducted, ensuring reliable findings that informed future research and practice were yielded.

This study applies the Web of Science (WoS), Scopus and Education Resources Information Center (ERIC) databases due to their extensive coverage of peer-reviewed journal articles across various disciplines. These databases are high-performance academic search engines essential for identifying relevant and high-quality studies in systematic research (Gusenbauer & Haddaway, 2020). In particular, ERIC is designed explicitly for education-related content, making it an imperative and contextually relevant resource for education research. Including these databases will broaden the literature search, increasing the reliability and relevance of high-quality review findings. Note that the final search was conducted on 2nd March 2025. Boolean operators AND/OR and the truncation mark were utilised to refine search results. Backward citation tracking was not employed. Only peer-reviewed journal articles were included, and grey literature was excluded to ensure the quality of the selected studies.

Identification

The identification process required a cross-database search to identify all relevant studies related to the scientist-school partnership in STEM. This step is imperative in the systematic review process as it aims to compile a comprehensive collection of related literature. The process begins by selecting keywords to search for related terms and synonyms, using dictionaries, thesauri, encyclopedias, and previous research. All relevant terms were identified, and search strings were created for the WoS, Scopus, and ERIC databases (refer to Table 1). About 767 publications were generated during the initial phase of the systematic review, sourced from the three databases pertinent to the study topic.

Table 1

The search string

Scopus	TITLE-ABS-KEY (scientist* AND school* AND (classroom OR teacher* OR student*) AND (stem OR science OR technology OR engineering OR mathematic*) AND partnership) Date of Access: 2nd March 2025
WoS	(scientist* AND school* AND (classroom OR teacher* OR student*) AND (stem OR science OR technology OR engineering OR mathematic*) AND partnership) Date of Access: 2nd March 2025
ERIC	(scientist AND school AND (classroom OR student OR teacher) AND (stem OR science OR technology OR engineering OR mathematics) AND partnership) Date of Access: 2nd March 2025

Screening

Screening represented the second step in the systematic searching strategy, where the 767 articles were scrutinised to assess their suitability for inclusion in the review. A set of criteria was established for the screening process (refer to Table 2). The first criterion is the publication timeline, published between 2016 and 2025. This timeframe was selected based on study maturity, which posits that a field is considered mature when numerous articles have been published (Kraus et al., 2020; Alexander, 2020). Consequently, the researchers' search yielded adequate articles, enhancing the capacity to identify the most pertinent and appropriate articles for the review process.

The second criterion concerned the publication type, which was limited exclusively to journals (Linares-Espinós et al., 2018). Articles published in journals undergo a rigorous peer review process to ensure high quality. Hence, selecting articles of the journal type helps the authors in maintaining the content's quality. The selected articles must also come from the final publication stage rather than the press publication stage. The authors also focused on language in the context of this review. Note that only English articles were considered and focused on social science and multidisciplinary research. After applying these criteria and removing 47 duplicated articles, 632 were excluded from the review, leaving 88 articles deemed suitable to advance to the eligibility process. The inclusion and exclusion criteria are shown in Table 2.

Table 2

The inclusion and exclusion criteria in screening

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2016 - 2025	< 2016
Literature type	Journal (Article)	Conference, Book, Review
Publication Stage	Final	In Press
Subject	Social sciences and multidisciplinary	Besides social sciences and multidisciplinary

Although several studies published between 2016 and 2025 met the initial keyword and time-frame criteria, some were excluded during the screening and eligibility stages for methodological and conceptual reasons. Articles were excluded if they lacked direct relevance to scientist-school STEM partnerships, focused on higher education or informal learning contexts rather than K-12 settings, were theoretical, commentary, or review papers rather than empirical studies, exhibited limited methodological transparency or insufficient data for extraction, or were inaccessible in full text. These exclusion criteria ensured that only methodologically rigorous and contextually relevant studies were included, thereby maintaining the quality and consistency of the evidence base in line with PRISMA recommendations (Moher et al., 2009; Okoli, 2015).

Eligibility

The authors re-evaluated all selected articles to ensure their relevance to the study's inclusion criteria and addressed the research questions. In this stage, the authors screened the articles' titles, abstracts, and methodology sections, where necessary. This process led to the exclusion of 43 articles due to a lack of focus on the scientist-school partnership, out-of-field titles not significantly related to the study's objective, and no full-text access. Consequently, 45 articles remained eligible for quality appraisal.

Quality appraisal

Quality appraisal was conducted post-selection using a structured six-question checklist adapted from Abouzahra et al. (2020), selected for its relevance to diverse empirical studies within STEM education. Each study was assessed independently by three expert reviewers using a three-point scale (Yes = 1, Partly = 0.5, No = 0). The six Quality Assessment (QA) questions are as follows:

- QA1. Is the purpose of the study clearly stated?
- QA2. Is the interest and the usefulness of the work clearly presented?
- QA3. Is the study methodology clearly established?
- QA4. Are the concepts of the approach clearly defined?
- QA5. Is the work compared and measured with other similar work?
- QA6. Are the limitations of the work clearly mentioned?

The scoring procedure to evaluate each QA question is as follows: Yes (Y) = 1 (fully met), Partly (P) = 0.5 (somewhat met), or No (N) = 0 (not met).

Three experts from STEM fields independently assess the study using the listed QA. If there were discrepancies in scoring, these were resolved through consensus discussion to ensure inter-rater reliability. If there were any studies scoring a total score below 4, they were excluded from the synthesis to maintain minimal methodological quality, while if there were borderline cases, they were flagged during data interpretation. The scores from all experts are carefully calculated based on the mean and subsequently totaled to establish the overall mark. To advance to the next stage, a study must achieve a total score of more than 4, ensuring that only studies fulfilling a certain quality standard are considered for further evaluation. Based on the summary of QA in Table 3, all 45 studies were agreed to meet the quality thresholds and included in the final thematic synthesis. Table 3 summarizes the quality scores and experts' agreement across all studies.

Table 3

Quality Assessments of Selected Articles

No.	Author & Year	QA1	QA2	QA3	QA4	QA5	QA6	Total Score	Percentage (%)
1	Abramowitz et al. (2024a)	1	1	1	1	0.5	1	5.5	91.67
2	Aslam et al. (2018)	1	1	1	1	0.5	0.5	5	83.33
3	Atias et al. (2023a)	1	1	1	1	1	1	6	100.00
4	Atias et al. (2023b)	1	1	1	1	1	1	6	100.00
5	Basche et al. (2016)	1	1	1	1	1	1	6	100.00
6	Bopardikar et al. (2023)	1	1	1	1	1	1	6	100.00
7	Burgin et al. (2016)	1	1	1	1	0.5	1	5.5	91.67
8	Çavaş et al. (2021)	1	1	1	1	1	1	6	100.00
9	Chamely-Wiik et al. (2019)	1	1	1	1	1	1	6	100.00
10	Childers & Jones (2017)	1	1	1	1	1	1	6	100.00
11	Dai (2023)	1	1	1	1	0.5	1	5.5	91.67
12	Ermeling & Yarbo (2016)	1	1	1	1	0.5	0.5	5	83.33
13	Fadzil et al. (2019)	1	1	1	1	0.5	1	5.5	91.67
14	Hagan et al. (2020)	1	1	1	1	1	1	6	100
15	Hellgren & Lindberg (2017)	1	1	1	1	1	0.5	5.5	91.67
16	Hsu (2018)	1	1	1	1	1	1	6	100
17	Hsu & Espinoza (2018)	1	1	1	1	1	1	6	100
18	Ismail et al. (2024)	1	1	1	1	0.5	1	5.5	91.67
19	Ismail et al. (2022)	1	1	1	1	0.5	1	5.5	91.67
20	Maina et al. (2021)	1	1	1	1	0.5	0.5	5	83.33
21	Masson et al. (2016)	1	1	1	1	0.5	0.5	5	83.33
22	Matiash et al. (2021)	1	1	1	1	0.5	0.5	5	83.33
23	McCollough et al. (2016)	1	1	1	1	0.5	0.5	5	83.33
24	Morris et al. (2021)	1	1	1	1	0.5	1	5.5	91.67
25	Ng & Fergusson (2019)	1	1	1	1	1	1	6	100
26	Ogodo et al. (2023)	1	1	1	1	0.5	0.5	5	83.33
27	Olitsky (2017)	1	1	1	1	1	0.5	5.5	91.67
28	Olitsky et al. (2020)	1	1	1	1	1	1	6	100
29	Peterson et al. (2024)	1	1	1	1	1	1	6	100
30	Puslednik & Brennan (2020)	1	1	1	1	0.5	1	5.5	91.67
31	Saat et al. (2021)	1	1	1	1	1	1	6	100
32	Saat et al. (2023)	1	1	1	1	0.5	0.5	5	83.33
33	Simms et al. (2024)	1	1	1	1	0.5	1	5.5	91.67
34	Snitynsky et al. (2019)	1	1	1	0.5	1	1	5.5	91.67
35	So et al. (2021)	1	1	1	1	0.5	0.5	5	83.33
36	Sprowls (2020)	1	1	1	1	0.5	0.5	5	83.33
37	Taylor et al. (2022)	1	1	1	1	1	0.5	5.5	91.67
38	Ufnar et al. (2017)	1	1	1	1	0.5	1	5.5	91.67
39	Ufnar et al. (2018)	1	1	1	1	1	1	6	100
40	Ufnar & Shepherd (2019)	1	1	1	1	1	1	6	100
41	Ufnar & Shepherd (2020)	1	1	1	1	0.5	0.5	5	83.33

No.	Author & Year	QA1	QA2	QA3	QA4	QA5	QA6	Total Score	Percentage (%)
42	Vamvakas et al. (2023)	1	1	1	1	1	0.5	5.5	91.67
43	Ware et al. (2019)	1	1	1	1	1	1	6	100
44	Westbrook et al. (2023)	1	1	1	1	1	1	6	100
45	Yawson et al. (2016)	1	1	1	1	0.5	0.5	5	83.33

Data Abstraction and Analysis

The authors reviewed the remaining 45 articles, focusing on the results and discussion sections while referencing other parts as necessary. The extracted data were organised in a table and validated by two co-authors to ensure relevance and minimise bias. An inductive thematic analysis was performed to identify patterns of meaning in qualitative data, addressing research questions concerning the impact of the partnership, challenges of implementing partnerships, and the best practices in the implementation of the scientist-school partnership. This analysis adhered to the six-step process by Braun and Clarke (2006) and involved the first authors and two co-authors. The process began with familiarising the data, coding significant features, grouping codes into potential themes, and gathering related information. Correspondingly, three main themes were identified and thoroughly reviewed to ensure their relevance to the extracted data.

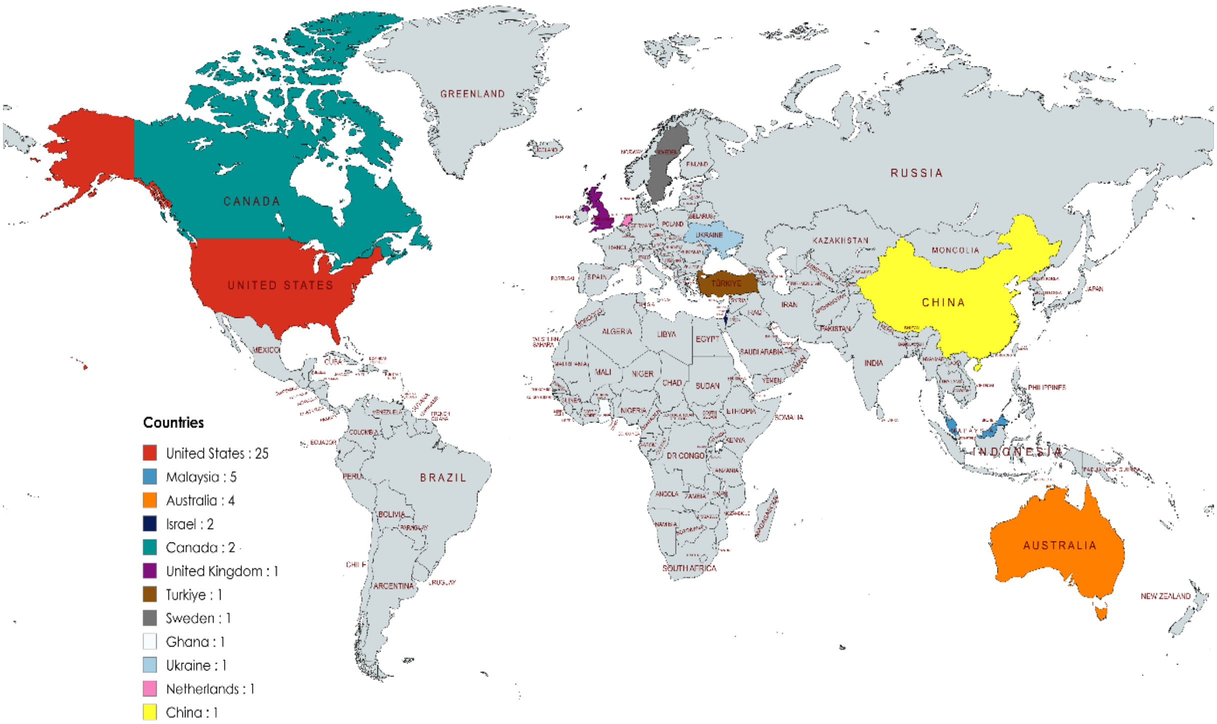
This study employed an integrative analysis to synthesise various research designs and identify pertinent topics and subtopics. Figure 1 illustrates the initial step involved in collecting data from 45 articles. The authors critically examine the key studies on scientist-school partnerships, focusing on methodologies and findings. Meanwhile, the co-authors collaborate to develop themes based on the evidence and maintain a log to document analyses and interpretations throughout the process. To resolve any inconsistencies in theme development, the authors engage in discussion to address disagreements and conduct an expert review phase, ensuring each sub-theme's clarity and relevance. Feedback from three STEM education experts facilitated refinements in the themes, ultimately enhancing the overall validity and trustworthiness of the findings.

Characteristics of the Selected Studies

A total of 45 studies were selected based on a search of relevant keywords. After a thorough review, all 45 studies were included in the sample. These articles were conducted in various countries: USA (n=25), Malaysia (n=5), Australia (n=4), Israel (n=2), Canada (n=2), the UK (n=1), Türkiye (n=1), Sweden (n=1), Ghana (n=1), Ukraine (n=1), The Netherlands (n=1), and China (n=1) as shown in Figure 2.

Figure 2

The countries involved in the scientist-school STEM partnership review



Among these were 21 qualitative, 9 quantitative, and 16 mixed-methods studies. An inductive thematic analysis of the research titles was conducted to generate themes for further in-depth analysis. Note that each article focuses on STEM fields. The overall emphasis of the study is on the STEM area. Additionally, a summary of the 45 studies is provided in Table 4, which outlines key aspects of the research:

a) School level: The level of the school institute was coded as Kindergarten (K) (ages 5-6), primary school (Grades 1-5: ages 6-11) and, secondary school which comprises of middle school (Grades 7-8: ages 12-13), and high school (Grades 9-12 or 13: ages 14-18),

b) STEM-related discipline: This information was collected from each study's title and abstract, whether under STEM-related subjects (science, technology, engineering, or mathematics).

c) Study design: The study's design (e.g., qualitative, quantitative or mixed methods) reflected the overall research framework and the particular research design. This data was obtained by analysing the method section of each research paper.

d) Participants' characteristics: Information on the number of participants or samples was obtained from each study's method section, text and tables.

e) Scientists' demographics: the demographics of the scientists, whether university scientists, industry scientists, or graduate students.

f) The partners involved: the partnership involving the scientists-teacher, scientist-students, or scientist-teacher-students.

g) Country of study: The location of the studies.

Table 4

Summary of studies

No.	Author & Year	School Level	Study Setting	STEM-related subject	Study Design	Participant / Population	Scientists' Demographics	Partner Involved	Country of Study
1	Abramowitz et al. (2024a)	Primary, Middle and High School	Classroom with scientists' visits	Science	Qualitative	Five teachers (two primary, two middle, one high school)	University scientists	Scientist-Teacher	USA
2	Aslam et al. (2018)	High School	West Midlands schools	STEM	Qualitative	11 teachers from 6 schools	University scientists	Scientist-Teacher	UK
3	Atias et al. (2023a)	High School	School-based citizen science projects	Science	Qualitative	Nine teacher-scientist pairs	University scientists	Scientist-Teacher	Israel
4	Atias et al. (2023b)	High School	Citizen science contributions	Science	Qualitative	Nine teacher-scientist pairs: seven science, one mathematics, one geography teacher	University scientists	Scientist-Teacher	Israel
5	Basche et al. (2016)	Middle School	Classroom with a scientist's partnership	Science	Mixed Methods	101 students in treatment, 329 peers for comparison	Graduate students	Scientist-Teacher-Student	USA
6	Bopardikar et al. (2023)	Middle School	Environmental education programme	Science	Qualitative	Four designers (two curriculum writers and two ecologists)	University scientists	Scientist-Teacher-Student	USA
7	Burgin et al. (2016)	Urban Primary School	Theatre performance in education	Science	Mixed Methods	62 3rd and 4th-grade students, 10 teachers	University scientists	Scientist-Teacher-Student	USA
8	Çavaş et al. (2021)	High Schools	Nationwide survey	STEM	Quantitative	301 Turkish STEM teachers	University scientists	Scientist-Teacher-Student	Turkey
9	Chamely-Wiik et al. (2019)	High School	GK-12 programme	STEM	Mixed Methods	24 graduate STEM students	Graduate students	Scientist-Student	USA
10	Childers & Jones (2017)	High School	Remote microscopy investigation	Science	Quantitative	72 high school students	University scientists	Scientist-Student	USA
11	Dai (2023)	Primary School	Professional Development Programme with scientists' partnership	Technology	Qualitative	Six primary teachers	University scientists	Scientist-Teacher	USA

No.	Author & Year	School Level	Study Setting	STEM-related subject	Study Design	Participant / Population	Scientists' Demographics	Partner Involved	Country of Study
12	Ermeling & Yarbo (2016)	High School	Learning Studios model	STEM	Qualitative	Two teacher teams and local scientists	University scientists	Scientist-Teacher	USA
13	Fadzil et al. (2019)	High School	Science classes	Science	Mixed Methods	125 Grade 10 students, eight teachers, seven scientists	University scientists	Scientist-Teacher-Student	Malaysia
14	Hagan et al. (2020)	High School	Classroom research-based project	Biology (Ecology)	Mixed Methods	One high school teacher, two university professors	University scientists	Scientist-Teacher	USA
15	Hellgren & Lindberg (2017)	High School	Medicine Hunt Project	Science	Quantitative	388 students in Grades 7–9	University scientists	Scientist-Teacher-Student	Sweden
16	Hsu (2018)	High School	Internship Programme	Science	Qualitative	36 High school students and four scientists	University scientists	Scientist-Student	USA
17	Hsu & Espinoza (2018)	High School	University internship	Science	Mixed Methods	42 High school students	University scientists	Scientist-Student	USA
18	Ismail et al. (2024)	High School	Science classroom	STEM	Qualitative	Six science teachers	University scientists	Scientist-Teacher	Malaysia
19	Ismail et al. (2022)	High School	Science classroom	STEM	Qualitative	Six students	University scientists	Scientist-Student	Malaysia
20	Maina et al. (2021)	Middle and High School	University summer PD programme	Data Science, Cybersecurity	Qualitative	Nine teachers	University scientists	Scientist-Teacher	USA
21	Masson et al. (2016)	High School	Technology design activity	Technology	Qualitative	29 high school students	University scientists	Scientist-Student	Netherlands
22	Matiash et al. (2021)	High School	University-school partnership	Mathematics	Mixed-methods	45 future mathematics teachers, 60 mathematics teachers, 15 mathematics lecturers	University scientists	Scientist-Teacher	Ukraine
23	McCollough et al. (2016)	Middle School	University-district partnership	STEM	Mixed Methods	45 future teachers + 60 working teachers + 15 trainers).	University scientists	Scientist-Teacher	USA
24	Morris et al. (2021)	High School	Teacher-industry collaboration	STEM	Qualitative	81 early-career teachers, four STEM industry professionals, and scientists.	Industry scientists	Scientist-Teacher	Australia
25	Ng & Fergusson (2019)	High School	Digital science module project	Science	Mixed Methods	49 science teachers	University scientists	Scientist-Teacher	Australia
26	Ogodo et al. (2023)	Primary School	University-community partnership	STEM	Mixed Methods	375 students and seven teachers	University scientists	Scientist-Teacher-Student	USA
27	Olitsky (2017)	K-12	K–20 partnership	Math and Science	Qualitative	Eight teachers and 21 faculty members	University scientists	Scientist-Teacher	USA

No.	Author & Year	School Level	Study Setting	STEM-related subject	Study Design	Participant / Population	Scientists' Demographics	Partner Involved	Country of Study
28	Olitsky et al. (2020)	High School	University-high school collaboration	Neuroscience	Mixed Methods	14 College and 80 high school students	University scientists	Scientist-Student	USA
29	Peterson et al. (2024)	Middle and High School	Forest data investigations	STEM	Mixed methods	10 university faculty members, 13 Science Teachers. Forest Scientists.	University scientists	Scientist-Teacher	USA
30	Puslednik & Brennan (2020)	High School (Rural)	Mentor-led research programme	Science	Quantitative	Nine Year 10 students	University scientists	Scientist-Student	Australia
31	Saat et al. (2021)	High School	School-university collaboration	STEM	Qualitative	Nine teachers, 10 scientists	University scientists	Scientist-Teacher-Student	Malaysia
32	Saat et al. (2023)	High School	STSP evaluation	STEM	Mixed Methods	125 students, nine teachers, 10 scientists, 267 teachers	University scientists	Scientist-Teacher-Student	Malaysia
33	Simms et al. (2024)	Primary School	Curriculum-based citizen science	Science	Qualitative	Grade 5 students, teachers	University scientists	Scientist-Teacher-Student	Canada
34	Snitynsky et al. (2019)	High School	University-teacher collaboration	Chemistry	Qualitative	Teachers and scientists	University scientists	Scientist-Teacher	Canada
35	So et al. (2021)	Primary School	Classroom-STEM professional collaboration	STEM	Qualitative	Five teachers	University scientists	Scientist-Teacher	China
36	Sprowls (2020)	High School	Science outreach programme	Science	Qualitative	10 students, 10 scientist mentors	Graduate students and university scientists	Scientist-Teacher-Student	USA
37	Taylor et al. (2022)	High School	Photosynthesis/respiration module with scientist mentoring	Science	Quantitative	36 teachers, high school students	Industry scientists	Scientist-Student	USA
38	Ufnar et al. (2017)	K-12	Classroom and summer programme	STEM	Mixed methods	84 fellows, 74 teachers	Graduate students	Scientist-Teacher-Student	USA
39	Ufnar et al. (2018)	Primary and Middle School	Co-teaching programme	STEM	Qualitative	Three Scientists and three teachers	Graduate students	Scientist-Teacher	USA
40	Ufnar & Shepherd (2019)	K–12	Long-term co-teaching	STEM	Mixed Methods	83 fellows and 74 teachers	Graduate students and university	Scientist-Teacher	USA

No.	Author & Year	School Level	Study Setting	STEM-related subject	Study Design	Participant / Population	Scientists' Demographics	Partner Involved	Country of Study
							scientists		
41	Ufnar & Shepherd (2020)	Middle and High School	GK-12 adapted partnership	STEM	Mixed-methods	138 middle and high school teachers,184 fellows	Graduate students	Scientist-Teacher	USA
42	Vamvakas et al. (2023)	High School	Digital resource development	Science	Mixed Methods	74 Science teachers and students	University scientists	Scientist-Teacher	Australia
43	Ware et al. (2019)	High School	Environmental science outreach	Science	Mixed methods	108 Students, professionals mentor	Graduate students and university scientists	Scientist-Teacher	USA
44	Westbrook et al. (2023)	High School	PlantingScience STSP	Biology	Quantitative	1,535 students from high schools, 64 teachers	Graduate students, university scientists, and industrial scientists	Scientist-Student	USA
45	Yawson et al. (2016)	High School	Classroom neuroscience outreach	Science	Quantitative	44 junior high school students	Undergraduate students, graduate teaching assistants, and university scientists	Scientist-Student	Ghana

Table 5 presents the distribution of studies according to their focus on STEM subjects. Most studies (n = 24) concentrated on science, underscoring its significant role in partnerships between scientists and schools, particularly in biology, environmental science, and neuroscience. Additionally, 18 studies implemented integrated STEM approaches, indicating a growing trend toward interdisciplinary teaching that reflects real-world problem-solving scenarios. However, Technology (n = 2) and Mathematics (n = 1) were notably underrepresented, and Engineering was absent as a standalone subject in this review.

Table 5

Number of studies in STEM-related subjects

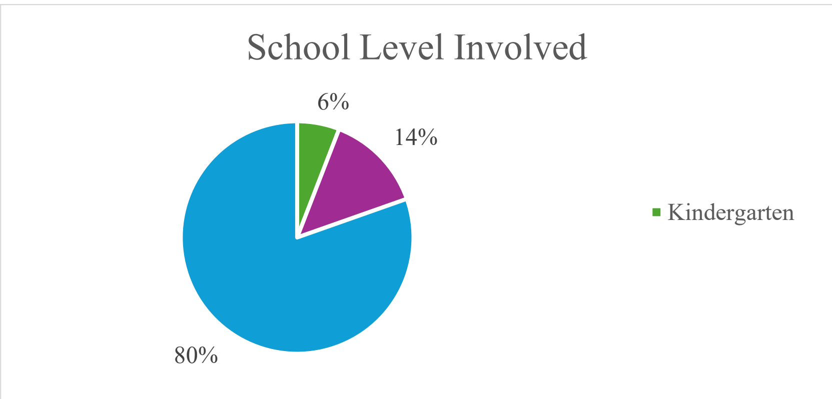
Subjects	Number of Studies	Percentage (%)
Science	24	53
Technology	2	4
Engineering	0	0
Mathematics	1	2
Integrated STEM	18	41
Total	45	100

Most of the participants in the selected studies are from STEM disciplines. However, several studies also highlight the importance of the integration of STEM with the social sciences and the humanities (Atias et al., 2023b; Çavaş et al., 2021; So et al., 2021), particularly emphasising geography in tackling environmental issues (Atias et al., 2023b). Çavaş et al. (2021) propose that STEM partnerships can expand to include geography, values education, and history, underscoring the interdisciplinary nature of STEM in imparting essential skills, knowledge, and values.

The distribution of studies across school levels highlights a strong focus on secondary school settings, representing 80%, with 41 studies centred on secondary school (8 middle school and 33 high school) (see Figure 3). This may be due to the suitability of secondary school curricula for engaging students with complex scientific concepts and the feasibility of involving them in authentic research activities. The partnerships was implemented in seven primary schools, representing 14%, and three studies implemented in kindergartens show only 6%, reflecting a moderate interest in STEM partnership experiences for younger learners. The total number of school-level studies exceeds 45 because seven studies addressed K-12 or mixed school levels, indicating adaptability across age groups. The lower representation at the primary and kindergarten level may stem from challenges such as integrating age-appropriate content and limited science access. Meanwhile, partnerships are well-established in secondary schools, with increasing recognition of their value in middle and elementary education.

Figure 3

The school level involved in the review



An analysis of the demographics of scientists involved in school-based STEM partnerships (see Table 6) shows that university scientists are the most common collaborators, participating in 33 of 45 studies. This highlights the institutional nature of many initiatives, often arising from higher education outreach or teacher professional development. Graduate students contributed to 5 studies as co-teachers or research mentors, highlighting their role in STEM communication and professional growth. Collaborative models between graduate and university scientists were noted in another five studies. Industry scientists were involved in just two studies, indicating limited engagement from the professional STEM workforce. One study also included undergraduate students and graduate teaching assistants, showcasing a multilevel partnership model. The low involvement of undergraduate and industry partners suggests a potential area for growth in expanding career exposure and diversifying STEM role models for students, as shown in Table 6.

Table 6

Number of studies based on the scientist demographic

Scientist Demographic	Number of Studies	Percentage (%)
University Scientists	33	73.33
Graduate and University Scientists	5	11.11
Graduate Students	4	8.88
Industry Scientists	2	4.44
Undergraduate students, teaching assistants, and university scientists	1	2.22
Total	45	100

Findings and Discussion

Three themes were identified after the rigorous study of the recruited research papers, and the analysis was processed to conclude. The finalized themes and their detailed descriptions are outcomes of scientist-school STEM partnerships, challenges in implementing scientist-school STEM partnerships, and best practices for sustainable scientist-school STEM partnerships.

Outcomes of Scientist-School STEM Partnerships

Selected studies show that scientist-school partnerships yield significant outcomes for various stakeholders, including students, teachers, scientists, and educational institutions. Based on the thematic analysis of the reviewed studies, it was found that a significant amount of the studies highlight the outcomes of the partnership for teachers, followed by students, scientists, and institutions. Scientist-school partnerships benefit teachers by providing broader connections to the scientific community (31 studies), improving their science skills and practices (29 studies), increasing opportunities for them to develop collaborative lessons (22 studies), increasing teachers' pedagogical content knowledge (20 studies), increasing teaching confidence (11 studies), facilitating opportunities to co-teach with scientists (8 studies), and increasing teachers' positive attitudes towards STEM teaching (7 studies) as shown in Figure 4. Table 7 details the studies that report on teachers' outcomes.

Figure 4

The teachers' outcomes of the scientist-school STEM partnership

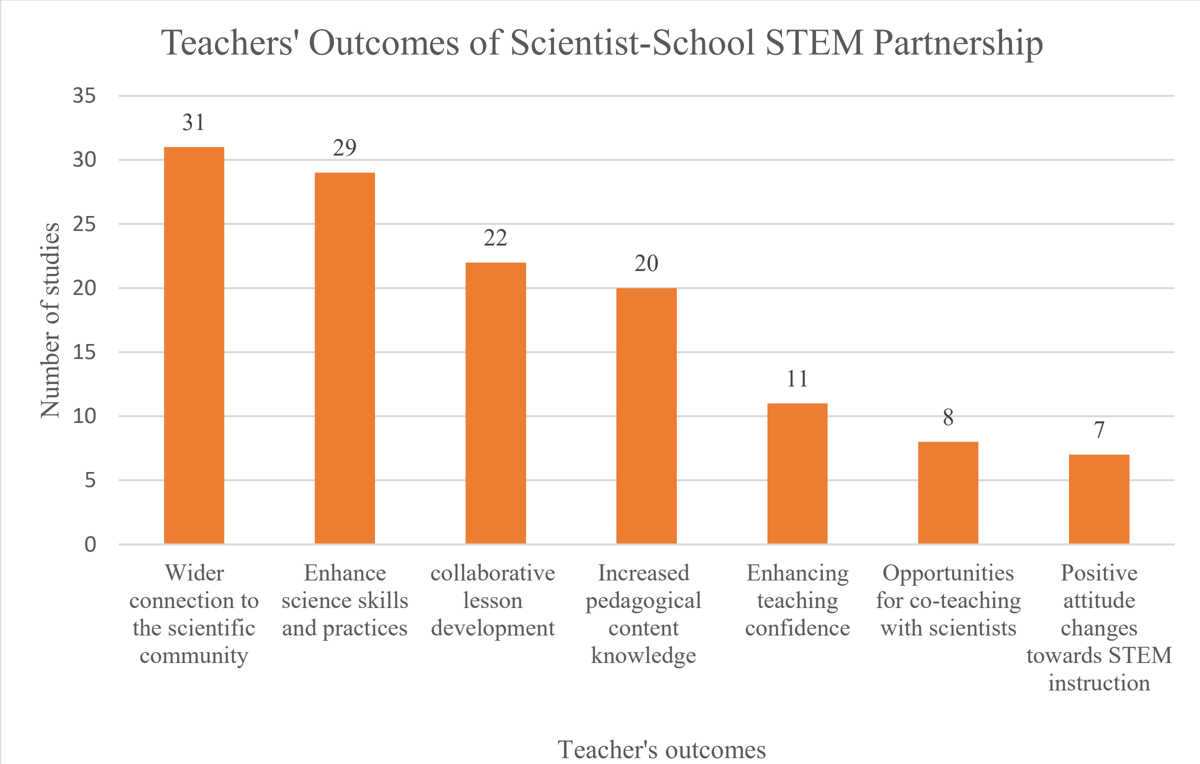


Table 7

The studies related to the outcomes gained by the teachers

Teachers' outcomes	Number of studies	Reviewed Studies
Wider connection to the scientific community	31	Aslam et al. (2018); Atias et al. (2023b); Basche et al. (2016); Çavaş et al. (2021); Chamely-Wiik et al. (2019); Childers & Jones (2017); Fadzil et al. (2019); Hagan et al. (2020); Hsu & Espinoza (2018); Ismail et al. (2022, 2024); Maina et al. (2021); McCollough et al. (2016); Morris et al. (2021); Ogodo et al. (2023); Olitsky (2017); Olitsky et al. (2020); Peterson et al. (2024); Puslednik & Brennan (2020); Saat et al. (2021, 2023); Simms et al. (2024); So et al. (2021); Sprowls (2020); Tytler (2018); Ufnar et al. (2018); Ufnar et al. (2017); Ufnar & Shepherd (2019, 2020); Vamvakas et al. (2023); Ware et al. (2019)
Enhance science skills and practices	29	Abramowitz et al. (2024a); Aslam et al. (2018); Bopardikar et al. (2023); Burgin et al. (2016); Çavaş et al. (2021); Chamely-Wiik et al. (2019); Ermeling & Yarbo (2016); Hagan et al. (2020); Hellgren & Lindberg (2017); Ismail et al. (2024); Maina et al. (2021); Matiash et al. (2021); McCollough et al. (2016); Morris et al. (2021); Ng & Fergusson (2019); Ogodo et al. (2023); Olitsky (2017); Peterson et al. (2024); Saat et al. (2021, 2023); Simms et al. (2024); Snitynsky et al. (2019); So et al. (2021); Taylor et al. (2022); Ufnar et al. (2018); Ufnar et al. (2017); Ufnar & Shepherd (2019, 2020); Ware et al. (2019)
Collaborative lesson development	22	Abramowitz et al. (2024a); Basche et al. (2016); Chamely-Wiik et al. (2019); Dai (2023); Ermeling & Yarbo (2016); Fadzil et al. (2019); Hagan et al. (2020); Hellgren & Lindberg (2017); Ismail et al. (2024); Maina et al. (2021); McCollough et al. (2016); Ogodo et al. (2023); Olitsky (2017); Olitsky et al. (2020); Peterson et al. (2024); Saat et al. (2021, 2023); So et al. (2021); Sprowls (2020); Ufnar et al. (2018); Ufnar & Shepherd (2020); Westbrook et al. (2023)
Increased pedagogical content knowledge	20	Basche et al. (2016); Bopardikar et al. (2023); Çavaş et al. (2021); Dai (2023); Ermeling & Yarbo (2016); Ismail et al. (2024); Maina et al. (2021); Matiash et al. (2021); McCollough et al. (2016); Morris et al. (2021); Ng & Fergusson (2019); Olitsky (2017); Peterson et al. (2024); Saat et al. (2021, 2023); So et al. (2021); Ufnar

		et al. (2018); Ufnar et al. (2017); Ufnar & Shepherd (2019, 2020)
Enhancing teaching confidence	11	Abramowitz et al. (2024a); Maina et al. (2021); Morris et al. (2021); Olitsky (2017); Olitsky et al. (2020); Saat et al. (2021); So et al. (2021); Ufnar et al. (2018); Ufnar et al. (2017); Ufnar & Shepherd (2019, 2020)
Opportunities for co-teaching with scientists	8	Atias et al. (2023a); Bopardikar et al. (2023); Olitsky (2017); Peterson et al. (2024); Snitynsky et al. (2019); Ufnar et al. (2018); Ufnar & Shepherd (2019, 2020)
Positive attitude changes towards STEM instruction	7	Çavaş et al. (2021); Hellgren & Lindberg (2017); Ismail et al. (2022); McCollough et al. (2016) Saat et al. (2021); So et al. (2021); Ufnar & Shepherd (2019)

Numerous studies have underscored the beneficial outcomes of STEM partnerships for students. These outcomes include enhanced career aspirations (18 studies), increased engagement in STEM learning (17 studies), improved content knowledge (11 studies), enhanced science attitudes (10 studies), greater interest in STEM fields (7 studies), the development of essential STEM skills (7 studies), increased enjoyment of science (7 studies), improved students' attitudes toward scientists (6 studies), improved achievement in STEM subjects (5 studies), heightened student motivation (3 studies), boosted student confidence (2 studies), and strengthened science identity (2 studies) as shown in Figure 5. Collectively, these partnerships have had a profound and positive impact on various dimensions of students' educational experiences in STEM disciplines. Table 8 reveals the investigate that involved the students' outcomes.

Figure 5

The students' outcomes of the scientist-school STEM partnership

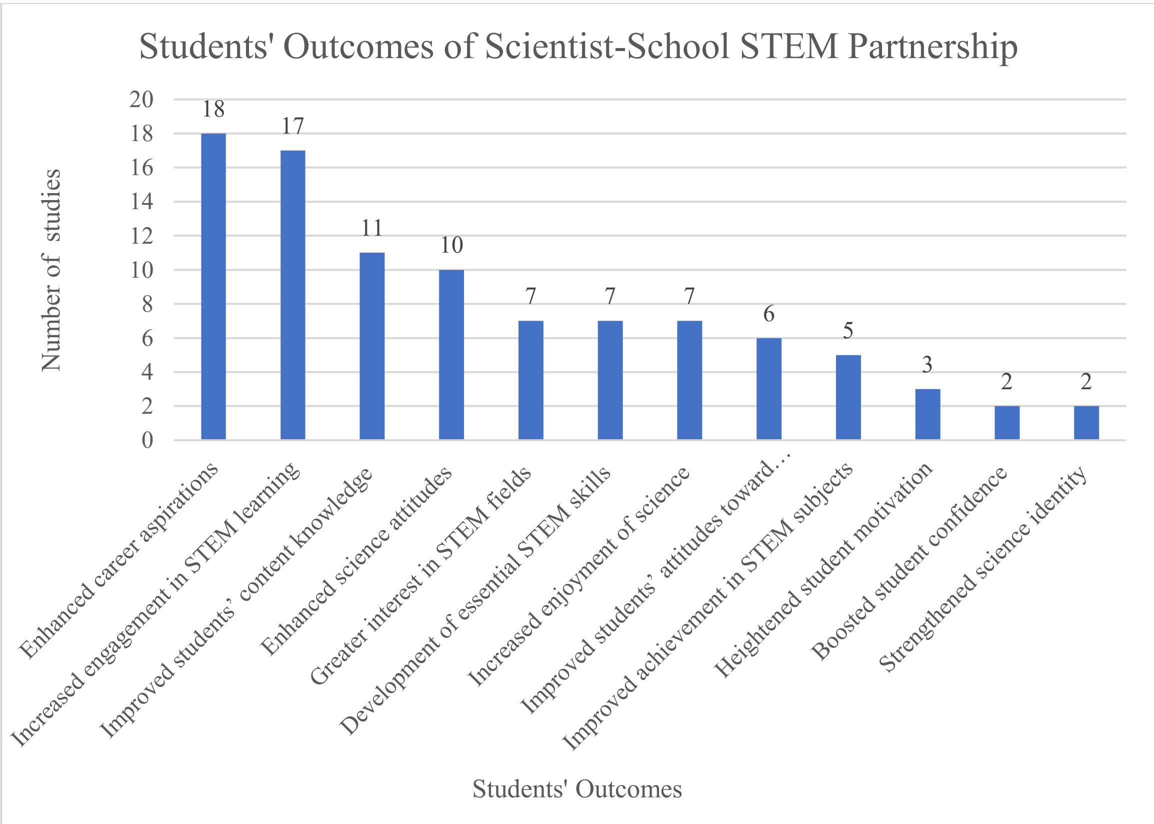


Table 8

The studies related to the outcomes gained by the students

Students' Outcomes	Number of studies	Reviewed studies
Enhanced career aspirations	18	Abramowitz et al. (2024a); Basche et al. (2016); Chamely-Wiik et al. (2019); Childers & Jones (2017); Fadzil et al. (2019); Hagan et al. (2020); Hellgren & Lindberg (2017); Ogodo et al. (2023); Olitsky et al. (2020); Puslednik & Brennan (2020); Saat et al. (2021); So et al. (2021); Ufnar et al. (2017); Ufnar & Shepherd (2019, 2020); Vamvakas et al. (2023); Westbrook et al. (2023); Yawson et al. (2016)
Increased engagement in STEM learning	17	Atias et al. (2023a); Basche et al. (2016); Bopardikar et al. (2023); Ermeling & Yarbo (2016); Fadzil et al. (2019); Ismail et al. (2022, 2024); McCollough et al. (2016); Morris et al. (2021); Olitsky et al. (2020); Saat et al. (2021, 2023); Sprowls (2020); Ufnar et al. (2017), Ufnar & Shepherd (2020); Vamvakas et al. (2023); Westbrook et al. (2023)
Improved students' content knowledge	11	Abramowitz et al. (2024a); Basche et al. (2016); Bopardikar et al. (2023); Çavaş et al. (2021); Fadzil et al. (2019); Hellgren & Lindberg (2017); Maina et al. (2021); McCollough et al. (2016); Olitsky et al. (2020); Saat et al. (2023); Westbrook et al. (2023)
Enhanced science attitudes	10	Basche et al. (2016); Childers & Jones (2017); Fadzil et al. (2019); Hellgren & Lindberg (2017); Ismail et al. (2024); Masson et al. (2016); McCollough et al. (2016); Olitsky et al. (2020); Ufnar et al. (2017); Yawson et al. (2016)
Greater interest in STEM fields	7	Abramowitz et al. (2024a); Bopardikar et al. (2023); Childers & Jones (2017); McCollough et al. (2016); Saat et al. (2021); Ufnar & Shepherd (2020); Yawson et al. (2016); (Westbrook et al., 2023)
Development of essential STEM skills	7	Chamely-Wiik et al. (2019); Hsu (2018); Ismail et al. (2022, 2024); Puslednik & Brennan (2020); Ufnar et al. (2017); Westbrook et al. (2023)
Increased enjoyment of science	7	Basche et al. (2016); Hellgren & Lindberg (2017); Ismail et al. (2024); Masson et al. (2016); Ufnar et al. (2017); Ufnar & Shepherd (2020); Yawson et al. (2016)
Improved students' attitudes toward scientists	6	Bopardikar et al. (2023); Çavaş et al. (2021); Fadzil et al. (2019); Taylor et al. (2022); Vamvakas et al. (2023); Westbrook et al. (2023)
Improved achievement in STEM subjects	5	Ermeling & Yarbo (2016); Masson et al. (2016); Saat et al. (2021); Taylor et al. (2022); Westbrook et al. (2023)
Heightened student motivation	3	Aslam et al. (2018); Childers & Jones (2017); Fadzil et al. (2019)
Boosted student confidence	2	Basche et al. (2016); Childers & Jones (2017)
Strengthened science identity	2	Childers & Jones (2017); Simms et al. (2024)

Additionally, scientists benefit from this partnership in various ways. These include improved communication and public engagement skills (15 studies), enhanced pedagogical knowledge (4 studies), a greater appreciation for K-12 pedagogy and learning diversity (3 studies), opportunities to inspire future generations (3 studies), and improved technological knowledge (1 study). The studies related to the outcomes gained by the scientists are shown in Table 9.

Table 9

The studies related to the outcomes gained by the scientists

Scientists' Outcomes	Number of studies	Reviewed Studies
Improved communication and public engagement skills	15	Atias et al. (2023a); Bopardikar et al. (2023); Chamely-Wiik et al. (2019); Matiash et al. (2021); Ogodo et al. (2023); Olitsky (2017); Olitsky et al. (2020); Peterson et al. (2024); Saat et al. (2021); Ufnar et al. (2017, 2018); Ufnar & Shepherd (2019, 2020); Westbrook et al. (2023); Yawson et al. (2016)
Enhanced pedagogical knowledge	4	Sprowls (2020); Ufnar & Shepherd (2019; 2020); Ufnar et al. (2018)
Greater appreciation of K-12 pedagogy and learning diversity	3	Ufnar et al. (2017); Masson et al. (2016); Hagan et al. (2020)
Opportunities to inspire future generations	3	Taylor et al. (2022); Olitsky et al. (2020); Snitynsky et al. (2019)
Improved technological knowledge	1	Ufnar & Shepherd (2020)

Furthermore, policymakers and institutional partners derive significant benefits from these collaborations. They obtain valuable insights for making informed decisions regarding the design of STEM curricula and programs (Yawson et al., 2016; Saat et al., 2023; Dai, 2023). Additionally, they gather evidence to support sustainable education-industry partnerships (Ismail et al., 2024; Westbrook et al., 2023; Vamvakas et al., 2023) and develop frameworks that promote inclusive and equitable outreach in STEM fields (So et al., 2021; Ufnar & Shepherd, 2020; Morris et al., 2021).

These partnerships have revealed numerous positive impacts attributable to a range of partnership models implemented globally. These models include the Scientist in the Classroom Partnership (SCP) (Ufnar et al., 2018; Ufnar & Shepherd, 2020), the Scientist in School programme and Scientist-Teacher Partnership (Abramowitz et al., 2024a), the Planting Science program by STSP (Taylor et al., 2022; Westbrook et al., 2023), and the What's in Our Waters (WOW) educational outreach program (Ware et al., 2019) which have been implemented in the USA, and Another program is Scientist-Teacher-Student Partnership (STSP) (Çavaş et al., 2021; Fadzil et al., 2019; Ismail et al., 2022, 2024; Saat et al., 2021, 2023) which has been implemented in Malaysia and Turkey. The skills, experience, and ideas that STEM experts contribute are significant inputs that can support designing desired instructional practices.

Challenges in Implementing Scientist-School STEM Partnerships

While STEM partnerships offer numerous benefits, partners encounter several challenges that hinder effective collaboration. These challenges include time constraints (20 studies), integrating activities into the curriculum (11 studies), limited access to materials and resources (6 studies), securing support from administration and the school (5 studies), the use of scientific language by scientists that is hard to understand (5 studies), insufficient funding (4 studies), communication barriers (4 studies), inadequate use of technology (3 studies), and gaps in content knowledge (3 studies) as shown in Figure 6. A summary of the reviewed studies on related to the challenges in implementing successful scientist-school STEM partnerships is shown in Table 10.

Figure 6

The Challenges of the Scientist-School STEM Partnership

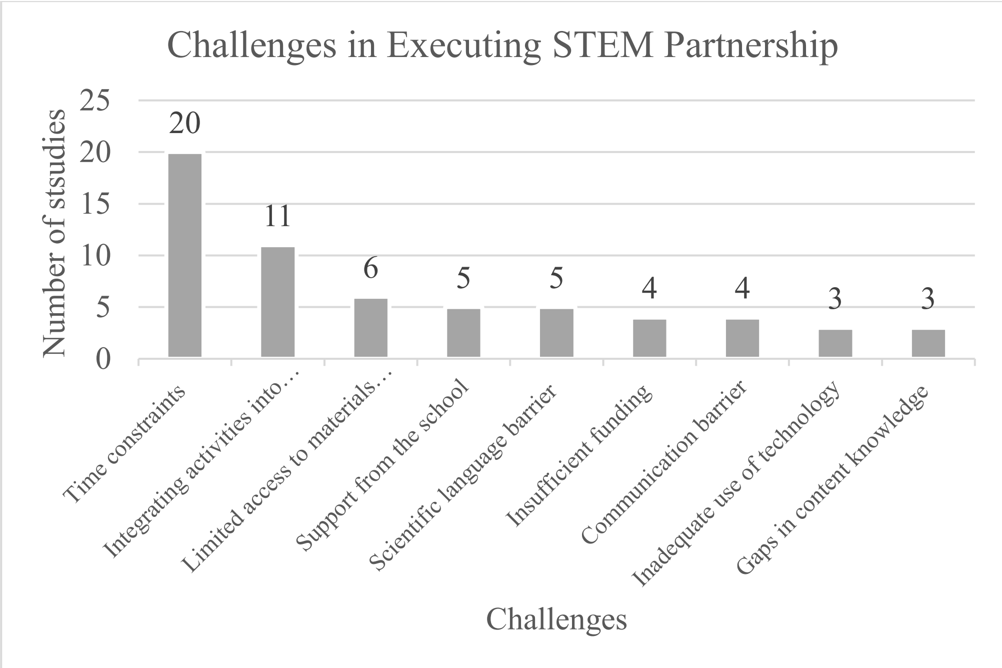


Table 10

The challenges of ımplementing the scientist-school STEM partnership

Challenges	Number of studies	Reviewed studies
Time constraints	20	Aslam et al. (2018); Bopardikar et al. (2023); Çavaş et al. (2021); Chamely-Wiik et al. (2019); Ermeling & Yarbo (2016); Fadzil et al. (2019); Hagan et al. (2020); Hsu (2018); Maina et al. (2021); McCollough et al. (2016); Morris et al. (2021); Ogodo et al. (2023); Olitsky (2017); Olitsky et al. (2020); Peterson et al. (2024); Saat et al. (2023); Simms et al. (2024); Ufnar et al. (2018); Ufnar & Shepherd (2020); Westbrook et al. (2023)
Integrating activities into curriculum	11	Aslam et al. (2018); Bopardikar et al. (2023); Hellgren & Lindberg (2017); Ismail et al. (2024); Maina et al. (2021); McCollough et al. (2016); Morris et al. (2021); Peterson et al. (2024); Saat et al. (2023); So et al. (2021); Ufnar et al. (2017)
Limited access to materials and resources	6	Bopardikar et al. (2023); Hsu (2018); Morris et al. (2021); Saat et al. (2023); Simms et al. (2024); So et al. (2021)
Support from the administration and the school	5	Abramowitz et al. (2024a); Aslam et al. (2018); Hsu (2018); Ogodo et al. (2023); Saat et al. (2023)
Scientific language barrier	5	Chamely-Wiik et al. (2019); Hsu (2018); Olitsky (2017); Peterson et al. (2024); Westbrook et al. (2023)
Insufficient funding	4	Aslam et al. (2018); Childers & Jones (2017); Ogodo et al. (2023); Ufnar & Shepherd (2020)
Communication barrier	4	Bopardikar et al. (2023); Hsu (2018); Masson et al. (2016); Snitynsky et al. (2019)
Inadequate use of technology	3	Abramowitz et al. (2024a); Masson et al. (2016); Morris et al. (2021)
Gaps in content knowledge	3	Bopardikar et al. (2023); Hsu (2018); Saat et al. (2021)

Best practices for scientist-school STEM partnerships

The collaboration between scientists and schools in STEM education has garnered significant global attention in recent decades. Future research can benefit from emulating the best practices identified in prior studies. The best practices established in these scientist-school STEM partnerships include providing authentic science experiences aligned with classroom content (28 studies), ensuring curriculum alignment or integration within existing curricular frameworks (27 studies), obtaining essential support resources or funding (17 studies), incorporating technology and digital tools (10 studies), defining clear reform goals for partners in the community of practice and the school (7 studies), engaging in long-term co-teaching and co-design initiatives (5 studies), localizing content to make it relevant to students' lives (4 studies), and expanding STEM partnerships to include the humanities or social sciences fields (3 studies). These practices underscore the critical elements that contribute to effective collaborations in STEM education. Figure 7 illustrates the best practices for a sustainable scientist-school STEM partnership, followed by the studies related to the best practices for sustainable scientist-school STEM partnership, which are shown in Table 11.

Figure 7

The best practices for sustainable scientist-school STEM partnership

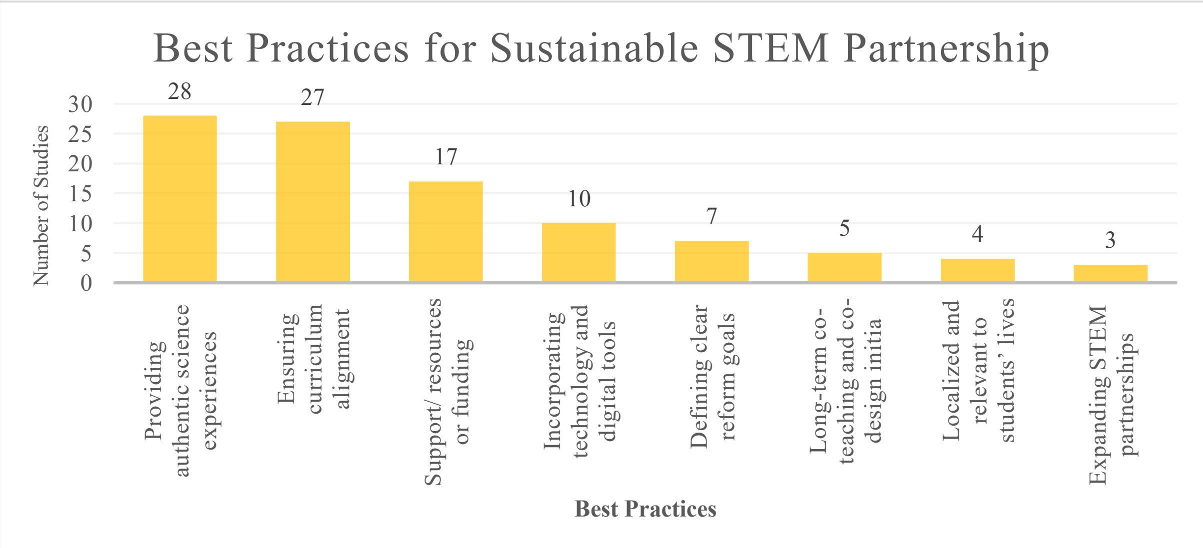


Table 11

The studies related to the best practices for sustainable scientist-school STEM partnership

Best Practices	Number of studies	Reviewed Studies
Providing authentic science experiences that are aligned with classroom content	28	Abramowitz et al. (2024a); Atias et al. (2023b); Basche et al. (2016); Bopardikar et al. (2023); Burgin et al. (2016); Çavaş et al. (2021); Chamely-Wiik et al. (2019); Fadzil et al. (2019); Hagan et al. (2020); Hellgren & Lindberg (2017); Ismail et al. (2022, 2024); Maina et al. (2021); Masson et al. (2016); McCollough et al. (2016); Morris et al. (2021); Olitsky (2017); Olitsky et al. (2020); Peterson et al. (2024); Puslednik & Brennan (2020); Saat et al. (2021, 2023); Simms et al. (2024); So et al. (2021); Ufnar et al. (2018); Ufnar et al. (2017); Vamvakas et al. (2023); Westbrook et al. (2023)
Ensuring curriculum alignment	27	Aslam et al. (2018); Basche et al. (2016); Bopardikar et al. (2023); Çavaş et al. (2021); Chamely-Wiik et al. (2019); Dai (2023); Fadzil et al. (2019); Hellgren & Lindberg (2017); Ismail et al. (2024); Maina et al. (2021); Masson et al. (2016); McCollough et al. (2016); Morris et al. (2021); Ogodo et al. (2023); Olitsky (2017); Peterson et al. (2024); Puslednik

		& Brennan (2020); Saat et al. (2021, 2023); Simms et al. (2024); Snitynsky et al. (2019); So et al. (2021); Ufnar et al. (2017); Ufnar & Shepherd (2019, 2020); Vamvakas et al. (2023); Westbrook et al. (2023)
Support/ resources or funding	17	Abramowitz et al. (2024a); Basche et al. (2016); Chamely-Wiik et al. (2019); Fadzil et al. (2019); Maina et al. (2021); Masson et al. (2016); McCollough et al. (2016); Morris et al. (2021); Ng & Fergusson (2019); Saat et al. (2023); Simms et al. (2024); So et al. (2021); Ufnar et al. (2018); Ufnar et al. (2017); Ufnar & Shepherd (2019); Vamvakas et al. (2023); Yawson et al. (2016)
Incorporating technology and digital tools	10	Abramowitz et al. (2024a); Dai (2023); Masson et al. (2016); Matiash et al. (2021); Morris et al. (2021); Ng & Fergusson (2019); Saat et al. (2021); Snitynsky et al. (2019); So et al. (2021); Westbrook et al. (2023)
Defining clear reform goals for the partners and the school	7	Bopardikar et al. (2023); Hagan et al. (2020); Morris et al. (2021); Ogodo et al. (2023); Olitsky (2017); Saat et al. (2021, 2023)
Long-term co-teaching and co-design initiative	5	Atias et al. (2023b); Çavaş et al. (2021); Saat et al. (2023); Ufnar et al. (2018); Ware et al. (2019)
Localized and relevant to students’ lives	4	Basche et al. (2016); Simms et al. (2024); Saat et al. (2021, 2023)
Expanding STEM partnerships to include the humanities or social sciences field	3	Atias et al. (2023b); Çavaş et al. (2021); So et al. (2021)

Based on the studies reviewed, significant efforts have been made to establish effective partnerships. This process can be challenging, as it involves scientists, teachers, and students from diverse professional cultures and backgrounds. Despite these challenges, these best practices serve as a valuable guide for those embarking on a partnership or seeking to enhance an existing one. Additionally, partnerships formed within a global context take into account various factors that can be adapted to suit each specific environment. As the world navigates pressing global challenges such as climate change (Abramowitz et al., 2024a) and the rise of socioscientific issues (Falah et al., 2024), there is a growing imperative to broaden the scope of STEM education by integrating perspectives from the humanities and social sciences (Atias et al., 2023b; Çavaş et al., 2021; So et al., 2021). Addressing these complex issues requires an interdisciplinary approach that equips learners with the essential cross-cutting skills necessary for navigating an increasingly interconnected and uncertain world.

Conclusion and Implications

The findings of this systematic literature review on scientist-school STEM partnerships conducted between 2016 and 2025, reveal that these collaborations have garnered significant attention for their effectiveness in enhancing STEM education. It can be concluded that scientist-school STEM partnerships create a transformative avenue for enhancing STEM education by fostering multidimensional benefits, though their full potential is often constrained by systemic and structural complexities. The community of practice, which fosters collaboration between scientists teachers and students within a school environment, is vital for implementing STEM education that provides authentic learning experiences for students. Such partnerships offer substantial benefits not only to teachers, students, and scientists but also to institutions and policymakers, facilitating more effective approaches to empowering STEM education. Scientists, as subject-matter experts, should share their knowledge in collaboration with teachers, who possess a deeper understanding of their students' educational needs. Several challenges must be addressed, including time constraints, the integration of activities into an already crowded curriculum, limited access to materials and resources, inadequate support from school administration, barriers related to scientific language, insufficient funding, communication issues, the ineffective use of technology, and gaps in content knowledge. Despite these obstacles, a number of best practices can be employed to facilitate progress, such as offering authentic science experiences that are aligned with classroom content, ensuring curriculum alignment, securing adequate support, resources, and funding, incorporating technology and digital tools effectively, establishing clear reform goals for the partners and school initiating long-term co-teaching and co-design efforts, tailoring content to be relevant and localized to students' lives, expanding STEM partnerships to include the humanities and social sciences fields. This review underscores initiatives aimed at reinforcing and broadening the implementation of these partnerships, thereby ensuring that all stakeholders benefit and contribute to the advancement of STEM education.

Building on these findings, future research should employ longitudinal and cross-national designs to examine how partnership models evolve and sustain their impact over time. Future investigations should also consider extending the scope beyond STEM by integrating the humanities and social sciences to foster sustainability and a more human-centered approach to learning. For practitioners and policymakers, partnerships are most effective when co-designed by teachers and scientists, tightly aligned with curriculum and assessment standards, and supported through clear governance structures such as defined roles, timelines, and memoranda of understanding (MoUs). These collaborations should also include targeted professional development and equitable access to resources and participation. The purposeful use of digital tools, including remote data and collaboration platforms, should be accompanied by just-in-time technical support.

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Conflicts of Interest

The authors declare no conflicts of interest to report regarding the present study.

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