STEM Education

STEM Education, 5(1): 53–88
DOI: 10.3934/steme.2025004
Received: 06 August 2024
Revised: 07 November 2024
Accepted: 11 November 2024
Published: 05 December 2024

https://www.aimspress.com/journal/steme

Review

Navigating the challenges and future pathways of STEM education in Asia-Pacific region: A comprehensive scoping review

Fadhilah Jamaluddin[1], Ahmad Zabidi Abdul Razak[1] and Suzieleez Syrene Abdul Rahim[2,*]

[1] Department of Educational Management, Planning and Policy, Faculty of Education, Universiti Malaya, 50603 Kuala Lumpur, Malaysia; fadhilah.student@gmail.com, zabidi@um.edu.my

[2] Department of Mathematics and Science Education, Faculty of Education, Universiti Malaya, 50603 Kuala Lumpur, Malaysia; suzieleez@um.edu.my

* **Correspondence:** Email: suzieleez@um.edu.my; Tel: +60 12-293 7806.

Academic Editor: Feng-Kuang Chiang

Abstract: STEM education is crucial for driving economic growth, fostering technological innovation, and addressing global challenges in the Asia-Pacific region. In 2023, Malaysia and India emerged as leading contributors to STEM education. Malaysia excels with approximately 43.5% of tertiary students earning STEM degrees, while India, with 34.0% of its students in STEM, tops the global charts in STEM graduates due to its massive population of about 1.4 billion. With nine of the top ten emerging jobs by 2025 projected to be in STEM fields, these nations are well-positioned to meet future workforce demands. Recognizing this, we examined key challenges in STEM education and calls for strategic investments to achieve the Sustainable Development Goals. We leveraged the PRISMA-ScR framework and content analysis of literature from 2010 to 2024, identifying seven STEM education challenges across all levels of educational institutions: Teaching practices, learning approaches, gender disparities, location, career interest, student enrollment, and student soft skills. The most pressing challenges in STEM education are teaching practices, learning approaches, and gender disparities, with issues most pronounced at the secondary school level and continuing into higher education. The study's findings advance theoretical understanding of STEM education obstacles and provide a foundation for further research. Practically, this work offers crucial insights for educators, policymakers, and stakeholders, enabling the development of targeted interventions to improve teaching quality, enhance learning experiences, and foster gender inclusivity in STEM. Addressing these issues is vital to advancing Sustainable Development Goal 4, promoting a more accessible, equitable, and impactful STEM education across the Asia-Pacific region. This study thus enriches the literature on the challenges of STEM education by offering a comprehensive, unbiased review of past research, drawing broader conclusions, and outlining pathways for future exploration.

Keywords: STEM education; STEM fields; SDGs; teaching practices; learning approach; gender disparities; science; technology; engineering; mathematics

1. Introduction

Science, technology, engineering, and mathematics (STEM) education is a powerful catalyst for implementing and achieving the Sustainable Development Goals (SDGs). By raising awareness, enhancing knowledge, and equipping individuals with critical skills, STEM education empowers people to contribute meaningfully to global development efforts [1]. It plays a pivotal role in advancing the 2023 Development Agenda by providing the necessary tools for sustainable innovation and growth. STEM education is particularly crucial in supporting Goal 4 of the SDGs: ensuring inclusive and equitable quality education for all. By incorporating STEM subjects into curricula across all levels of education, students from diverse backgrounds, especially those from underrepresented groups, such as girls, are granted access to transformative learning experiences [2,3]. This fosters equity and ensures that all students can acquire the crucial skills needed to thrive in the 21st-century workforce. Hence, sustained investment in STEM education is essential for nations to meet future workforce demands and continue advancing sustainable development on a global scale [4].

The concept of STEM education can be understood from three key perspectives: STEM fields, STEM streams, and the STEM approach. STEM fields encompasses both traditional disciplines like medicine, engineering, chemistry, biology, mathematics, and statistics, as well as specialized fields such as astrophysics, biochemistry, and genetic engineering [5,6]. Moreover, STEM stream refers to the pathway for students in upper secondary school, allowing them to choose and focus on a specific STEM discipline based on their interests and strengths [5]. STEM approach is defined as a pedagogical strategy that integrates knowledge, skills, and values from science, technology, engineering, and mathematics. It emphasizes practical application to help students tackle real-world problems effectively [5]. This multifaceted understanding of STEM education highlights its broad scope, student-centric pathways, and practical teaching methods designed to equip students with the tools needed for innovative problem-solving in today's world.

In the Asia-Pacific region context, STEM education is particularly significant for promoting economic growth, technological advancement, employment, and addressing the pressing global challenges of the 21st century [7]. Many countries in the region, recognizing the transformative power of STEM, are prioritizing quality education in these fields to shape a generation of innovators and critical thinkers. This focus is essential for ensuring societal progress and producing graduates who are prepared to seize career opportunities in science, technology, engineering, and mathematics [2,4].

According to the data gathered by the UNESCO Institute for Statistics, in 2023, Malaysia and India, both prominent nations in the Asia-Pacific region, have emerged as leading contributors to STEM education. Malaysia is particularly notable, with approximately 43.5% of its tertiary students earning degrees in STEM fields. India, while slightly lower with 34.0% of its students pursuing

STEM degrees, produces the highest number of STEM graduates globally, owing its population of approximately 1.4 billion, the largest in the world [8]. This growing STEM output from countries like Malaysia and India aligns with the increasing demand for professionals in these fields. The "Future of Jobs Report 2020" by the World Economic Forum (WEF) emphasizes that nine out of the top ten emerging jobs in 2025 will be in STEM fields [9,10]. Consequently, this surge underscores the importance for countries in the region to not only sustain but also expand their investment in STEM education. By doing so, they will be better equipped to meet future workforce demands and contribute to advancing the SDGs.

Despite the notable successes in countries like Malaysia and India, the broader Asia-Pacific region continues to face significant challenges in advancing STEM education. Educational institutions across the region, from kindergartens to universities, grapple with issues including teaching practices (e.g., Li et al. [11], Arlinwibowo et al. [12], and Karpudewan et al. [13]), learning approaches (e.g., Way et al. [14], Beruin [15], and Manoharan and Kaur [16]), gender disparities (e.g., Wang [17], Jaremus [18], and Smith and Evans [19]), location (e.g., Murphy [20], Fraser et al. [21], and Zhai, Schneider and Krajcik [22]), career interest (e.g., Razali [23], Li et al. [24], and Mau, Chen and Lin [25]), student enrolment (e.g., Chew et al. [26], Bissaker [27], and Poy et al. [28]), and the student soft skills (e.g., Sutaphan and Yuenyong [29], Mutakinati, Anwari and Kumano [30], and Khalid et al. [31]). These challenges underscore the complexities of improving STEM education across the Asia-Pacific region, even in countries like Malaysia and India that are producing a high number of graduates. Addressing these issues is critical for fully unlicking the potential of STEM education and ensuring long-term innovation and economic growth across the Asia-Pacific region.

2. Literature review

Researchers focusing on Asia-Pacific region have delved into STEM education from a multitude of perspectives. A notable meta-analysis [32] revealed the challenges of STEM education, analyzing seven studies. Five of these focused specifically on the approaches teachers employ in STEM instruction, while the remaining two explored student's experiences in STEM learning environments. Another key study [33] conducted a comparative analyses of STEM education trends and status across five highly competitive countries in the Asia-Pacific region. The study evaluated STEM education in terms of background, current status, and emerging issues, offering a comprehensive synthesis of the distinct approaches and challenges faced in these countries. By comparing these aspects, the research provides valuable insights into the varying trajectories of STEM education development in the region, further highlighting both the opportunities and obstacles present in enhancing STEM learning across the Asia-Pacific region [33].

Apart from that, research by United Nations Development Programme (UNDP) provides an in-depth analysis of the emerging challenges and opportunities for women and girls in STEM across five countries in the Asia-Pacific region: China, Indonesia, Malaysia, Maldives, and Thailand [34]. The qualitative study reveals key issues affecting gender equality in STEM and explore potential solutions. Through qualitative analysis, the research highlights key issues and potential solutions for advancing gender equality in STEM fields. Its objectives are threefold: (1) To map the major challenges and opportunities for women in STEM throughout their life cycle, from birth to retirement; (2) to capture best practices and successful strategies that promote women's participation in STEM; and (3) to offer practical recommendations for stakeholders on how to effectively increase women's engagement in STEM careers. By emphasizing gender inclusivity, the research contributes to the broader regional efforts to strengthen STEM education and enhance diversity in STEM fields.

Next, a paper compiles efforts from science education researchers and practitioners across Asia-Pacific countries, including Indonesia, India, Japan, Malaysia, the Philippines, and Thailand. By employing thematic analysis, the results has revealed that students' declining interest and negative attitudes towards STEM education, often attributed to irrelevant and unengaging content. The prevalent didactic teaching approach fosters "inert knowledge," which lacks real-world context [35].

While studies have made significant strides in understanding various aspects of STEM education across Asia-Pacific region, to the best of our knowledge, no researcher has systematically examined the challenges of STEM education across all levels of educational institutions in the Asia-Pacific region. To fill this gap, we undertake a comprehensive scoping review of existing literature from 2010 to 2024, focusing on the challenges of STEM education across different educational levels.

This scoping review is guided by the following research questions:

Research Question 1 (RQ1): What types of challenges are most frequently found in relation to STEM education across Asia-Pacific region over a 14-year period (2010 – 2024)?

Research Question 2 (RQ2): At which levels of educational institutions are STEM challenges most commonly faced across Asia-Pacific region over a 14-year period (2010 – 2024)?

Research Question 3 (RQ3): What types of STEM challenges are encountered at different levels of educational institutions across Asia-Pacific region over a 14-year period (2010 – 2024)?

The scoping review approach is particularly suited for this study for several reasons. First, it allows for a broad exploration of a wide range of challenges across diverse educational contexts [36], making it ideal for mapping the landscape of STEM education challenges in such a varied region. Second, this methodology enables the identification of gaps in the existing literature, ensuring that areas needing further empirical investigation are uncovered [37]. Third, utilizing the PRISMA Extension for Scoping Reviews (PRISMA-ScR) framework ensures a systematic and transparent approach to synthesizing findings across multiple sources, enhancing the reliability and coherence of the review [38,39]. Finally, by analyzing studies over a 14-year period, the review provides timely and relevant insights into how these challenges have evolved, offering a comprehensive understanding for future research, policy development, and educational practices.

3. Materials and methods

This section describes the approach employed in obtaining and analyzing available literature on the challenges in STEM education throughout Asia-Pacific region. The preferred reporting items for the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) method is applied in order to retrieve all available studies, reviewing the steps in the process (identification, screening and eligibility), data abstraction, and data analysis, as PRISMA-ScR caters to two resource databases, including Web of Science (WoS) and Scopus.

3.1. PRISMA for scoping the reviews (PRISMA-ScR) method

In 2018, the PRISMA extension for scoping reviews (PRISMA-ScR) was released. When conducting a scoping review, the checklist includes 20 mandatory reporting items and two optional items. Scoping reviews are used to synthesize evidence and evaluate the breadth of literature on a specific topic. Among other objectives, scoping review assists in determining whether a systematic review of the literature is warranted [40]. Scoping reviews can be used to accomplished various goals. They may look into the extent (that is, the size), range (variety), and nature (characteristics) of the evidence on a particular topic or question; assess the value of conducting a systematic review; summarize findings from a heterogeneous body of knowledge in terms of methods or discipline; or identify gaps in the literature to aid in the planning and commissioning of future research [41].

The PRISMA-ScR was created in accordance with the EQUATOR (Enhancing the QUAlity and Transparency of Health Research) Network's published guidelines for the development of reporting guidelines [42]. The benefits of PRISMA-ScR incorporates the ability to (i) define specific and clear research questions, (ii) classify inclusion and exclusion criteria, and (iii) evaluate large databases of literature within a precise time frame [43]. Hence, PRISMA-ScR can conduct a thorough search for literature or papers pertaining to the challenges in STEM education.

3.2. Resources

The literature for this review is primarily compiled from two databases, WoS and Scopus, as they both offer comprehensive searching tools. WoS is an online citation indexing database, created by the Institute for Scientific Information but is now maintained by Clarivate Analytics. It is a multidisciplinary and selective bibliographic database made up of a number of specialized indexes organized by the type of indexed content or by theme [44]. WoS contains over 34,600 peer-reviewed journals [45]. It is one of the world's most highly regarded scientific citation search engines and is frequently used as an academic library research tool due to its comprehensive citation data [46]. As of 2023, on the other hand, Scopus has continued to expand its database, currently indexing over 90 million items, which include a vast range of peer-reviewed journals, conference proceedings, and patents. The platform now encompasses more than 27,950 active peer-reviewed journals from over 7,000 publishers worldwide [47]. This database contains the most peer-reviewed abstract and citation literature database, with smart tools for tracking, analyzing, and visualizing research, making research workflow effective and efficient [48].

3.3. Eligibility and exclusion criteria

The selection of studies for this scoping review has been guided by a rigorous set of inclusion and exclusion criteria, ensuring that the final dataset comprised only the most relevant and high-quality research. These criteria are designed to focus the review on journal articles offering substantive insights into the challenges in STEM education while excluding less relevant or incomplete sources. As portrayed in Table 1, the eligibility criteria are (i) types of publication, (ii) language, and (iii) focus of study.

The review includes only journal articles. This choice is made to prioritize sources that typically provide more comprehensive and thoroughly vetted research findings compared to other formats, such as conference papers or book chapters. Journal articles offer more mature, detailed, and peer-reviewed research [49]. The exclusion criteria, therefore, filtered out books, review articles, book series, data papers, chapters of books, conference papers, proceeding papers, and short surveys.

These types of publications are considered less relevant for this review because they often present preliminary findings, overviews, or opinions rather than in-depth empirical research.

Next, to ensure a more manageable and consistent literature review, only studies published in English are included. This decision is made to streamline the literature search and analysis process, given that the research team primarily operated in English. Non-English publications are excluded because translating large volumes of non-English material would have been resource-intensive and could introduce translation biases. Limiting the review to English-language publications also ensured that the findings were accessible to a broader international audience.

Last, the primary focus of this review is on challenges within STEM education. Therefore, only articles that directly addressed these challenges are included. STEM education is a critical area of research given its importance in preparing students for a future that increasingly demands strong technical and scientific skills. As such, any articles that contain outside the core challenges of STEM education are excluded from the review. The exclusion is essential to maintaining the scope and depth of the review, ensuring that it remains focused on the key research question.

Table 1. Scoping review inclusion and exclusion criteria.

Criteria	Inclusion	Exclusion
Types of publication	Journal articles including case studies	Books, review articles, book series, data paper, chapter of a book, proceedings papers, conference papers and short surveys
Language	English	Non-English
Focus of study	Challenges in STEM education	Other than challenges in STEM education

These criteria are designed to refine the literature search and ensure that the review includes only the most relevant, high-quality sources. By adhering strict inclusion and exclusion criteria, the review ensures that the final set of studies provided valuable insights into the specific challenges facing STEM education, while maintaining a high standard of academic rigor.

3.4. Scoping review process

A scoping review is a methodological tool utilized to map the key concepts within a research area, offering a comprehensive overview that sets the stage for further investigation. It provides a rigorous and detailed analysis of the state of the field, identifying trends, gaps, and questions that more targeted systematics reviews may address [50]. A scoping review is carried out by systematically searching, screening, and synthesize literature across a broad field to extract valuable insights, precisely definitions, key concepts, types of evidence as well as research gaps [51,52]. Scoping review is particularly beneficial for synthesizing knowledge and evidence from diverse sources [53]. The first step in conducting the scoping review involves identifying a set of relevant keywords for use in the literature search. These keywords are selected based on their relevance to the challenges in STEM education across the Asia-Pacific region. The databases WoS and Scopus are employed for the literature retrieval process, leveraging their comprehensive features to extract a robust dataset of research publications. Table 2 depicts the search strings employed in both databases.

Table 2. Search strings use in the scoping review.

Journal database	Search string	Frequency of hits
WoS	TOPIC: challenge* OR barrier* OR issue* AND "STEM education" OR "STEM field*" OR "Science, Technology, Engineering and Mathematics" OR "Science, Technology, Engineering and Mathematics Education" AND afghanistan OR "asia-pacific" OR australia OR bangladesh OR bhutan OR myanmar OR burma OR brunei OR cambodia OR china OR "Cook Islands" OR "Federated States of Micronesia" OR fiji OR india OR indonesia OR japan OR kiribati OR laos OR malaysia OR maldives OR "Marshall Islands" OR mongolia OR nepal OR "New Caledonia" OR "New Zealand" OR niue OR "North Korea" OR pakistan OR palau OR "Papua New Guinea" OR philippines OR singapore OR "Solomon Islands" OR "South Korea" OR "Sri Lanka" OR taiwan OR thailand OR timor-leste OR tonga OR tuvalu OR vanuatu OR vietnam	198
Scopus	(TITLE-ABS-KEY (challenge* OR barrier* OR issue*) AND TITLE-ABS-KEY ("STEM education" OR "STEM field*" OR "Science, Technology, Engineering and Mathematics" OR "Science, Technology, Engineering and Mathematics Education") AND TITLE-ABS-KEY (afghanistan OR "asia-pacific" OR australia OR bangladesh OR bhutan OR myanmar OR burma OR brunei OR cambodia OR china OR "Cook Islands" OR "Federated States of Micronesia" OR fiji OR india OR indonesia OR japan OR kiribati OR laos OR malaysia OR maldives OR "Marshall Islands" OR mongolia OR nepal OR "New Caledonia" OR "New Zealand" OR niue OR "North Korea" OR pakistan OR palau OR "Papua New Guinea" OR philippines OR singapore OR "Solomon Islands" OR "South Korea" OR "Sri Lanka" OR taiwan OR thailand OR timor-leste OR tonga OR tuvalu OR vanuatu OR vietnam))	348

In total, the search string matches 546 papers from WoS (198 papers) and Scopus (348 papers) combined. During the identification stage, 164 duplicate papers are removed, leaving 382 papers for further analysis. The screening process then excludes an additional 200 records, with these exclusions based on predefined criteria, such as the type of publication (e.g., books, conference papers, non-English records) and relevance to the research focused (i.e., published from 2010 onward). Following that, 182 articles proceed to the eligibility assessment stage. During this stage, 119 articles are excluded because they do not meet the criteria of addressing the core challenges in STEM education. Ultimately, 63 primary studies are fully extracted for detailed analysis, providing focused insights on the research topic.

The entire review process is demanding, requiring meticulous attention to detail and strict adherence to the review protocol [52]. Figure 1 illustrates the PRISMA-ScR flow diagram, which is followed to ensure transparency and methodological rigor during this scoping review process.

3.5. Data abstraction and analysis

The analysis involves 63 shortlisted papers. Descriptive analysis is used to summarize the selected papers, while content analysis addresses the research questions. Content analysis entails the systematic classification of content to identify recurring themes and patterns [54]. Specifically, data from each primary study are coded under broad themes, follows by an analysis of the occurrences of these themes [55].

The central theme of the current study focuses on the challenges in STEM education. The process begins with an examination of abstracts, followed by a thorough evaluation of the full papers. Raw data relevant to the research questions are extracted and manually coded into different themes using a spreadsheet (Excel). This manual coding process is crucial for identifying the specific challenges highlighted in the literature. The final results, along with every step of the procedure, are meticulously documented, ensuring the reliability and validity of the findings.

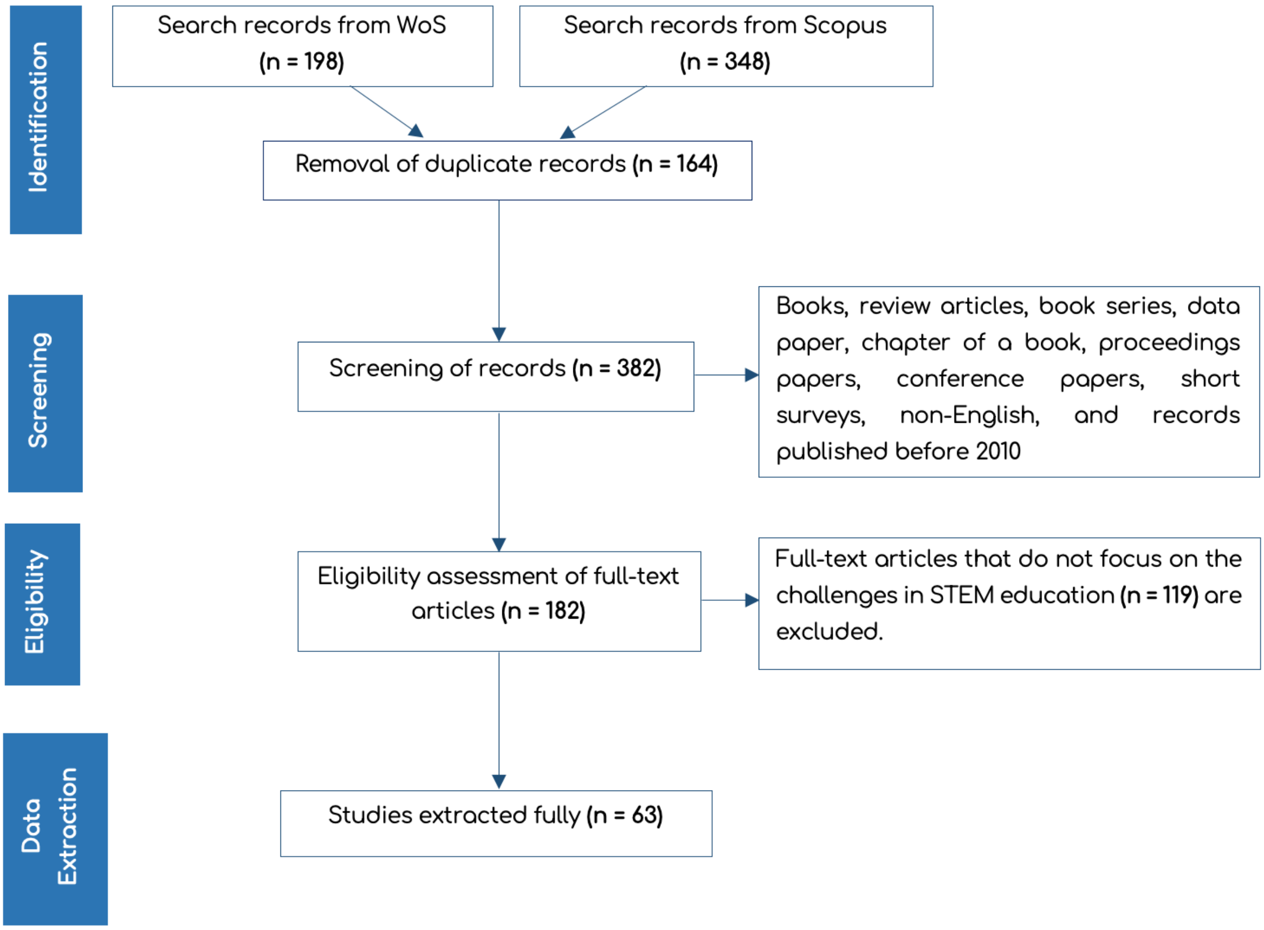

Figure 1. PRISMA-ScR flow diagram of the study.

4. Descriptive analysis

In this section, we provide a compelling overview of papers on the challenges in STEM education throughout Asia-Pacific region. Figure 2 illustrates the distribution of 63 selected articles on the challenges in STEM education across Asia-Pacific region from 2010 to 2024. It is depicted that the number of articles published each year fluctuates from 2010 to 2018, with notable peaks and troughs. A significant peak occurs in 2014, where four articles are published, marking the highest number of publications during the initial phase of this period. After this peak, however, there is a decline reaching a low point of only two articles 2018, indicating a temporary decrease in research interest and publication output.

Following the dip in 2018, there has been a marked resurgence in research interest, as evidenced by the steady increase in the number of published articles from 2018 to 2023. This upward trend suggests a growing awareness and recognition of the critical importance of addressing STEM education challenges in the region. The year 2023 has witnessed a remarkable milestone with 12 articles published, the highest number in the entire decade. This surge indicates a heightened level of research activity and renewed focus on understanding and addressing the complexities of STEM education in the Asia-Pacific region. Interestingly, the early months (first four months) of 2024 have already seen eight articles published, setting the stage for another productive year. This early momentum further reinforces the growing interest and engagement of researchers in this field.

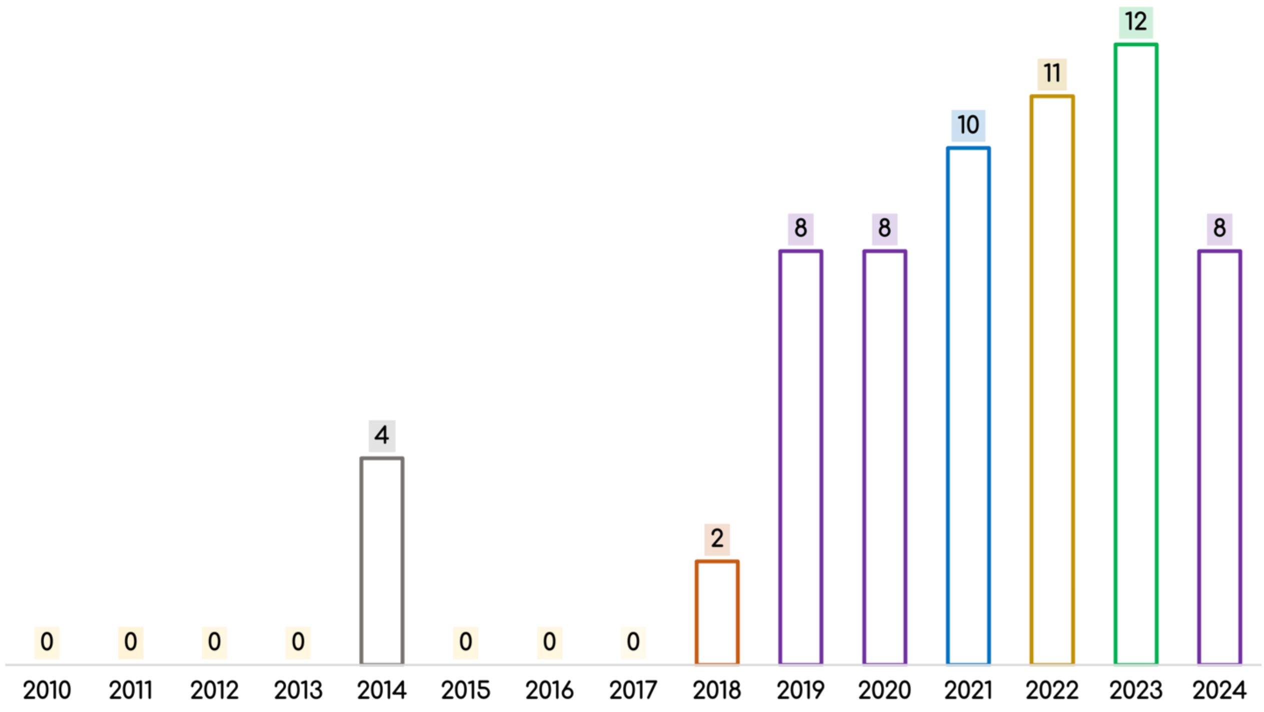

Figure 2. Article publication over time.

Figure 3 provides a valuable overview of the geographic distribution of research on STEM education challenges within the Asia-Pacific region. The 63 chosen articles are distributed across 15 countries in Asia-Pacific region. China has the most articles (14), followed by Australia and Malaysia with nine articles each, Singapore, Bangladesh, Philippines, and Taiwan with four articles each. Indonesia and Thailand have three articles each, while Cambodia, Vietnam and Japan have two articles each. The remaining three countries (New Zealand, South Korea, and India) each have one article.

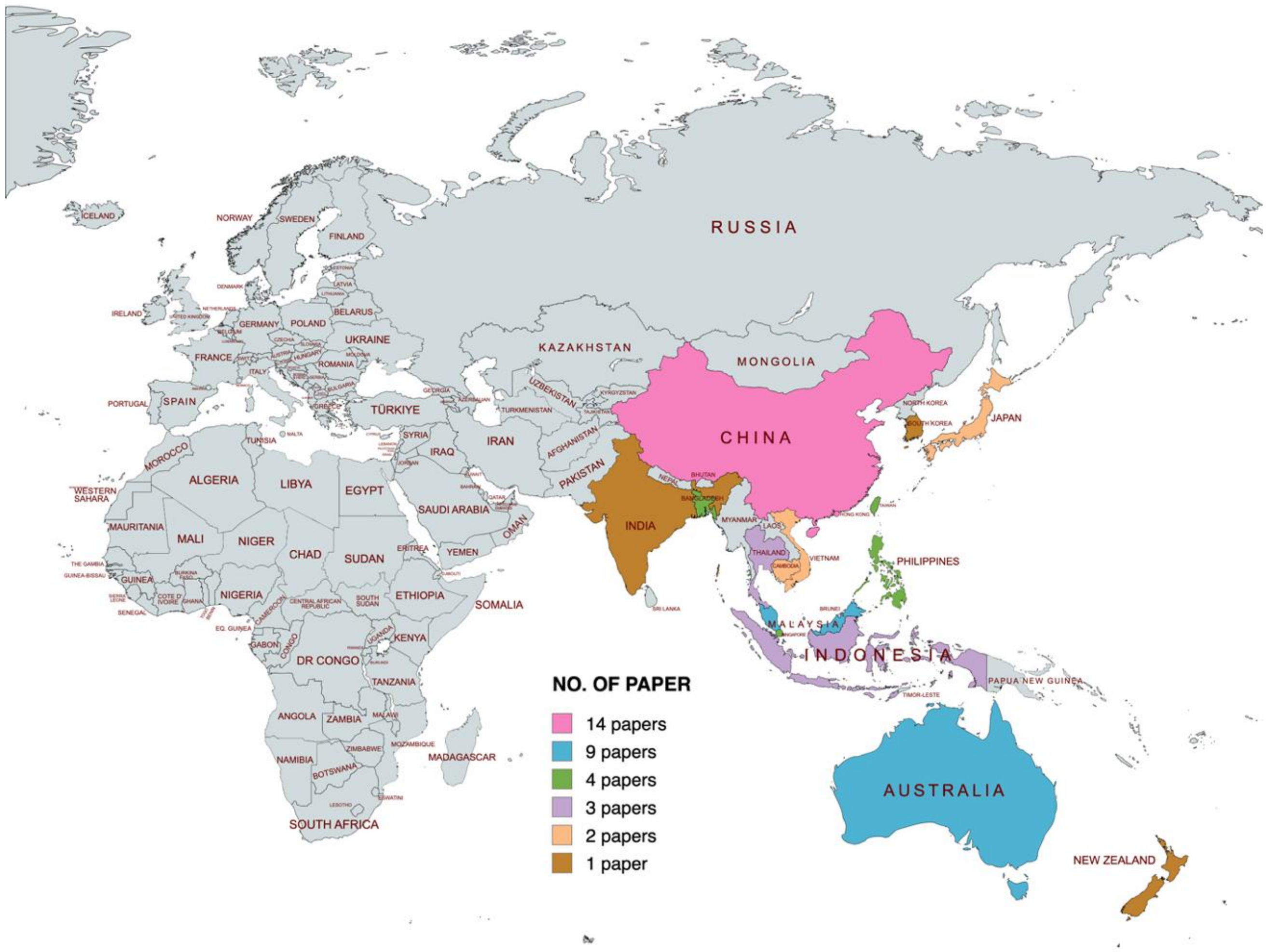

Figure 3. Geographical distribution of chosen articles per country.

It is unsurprising that China has the most articles addressing challenges in STEM education. As the third largest country in the world, China's approach to STEM education reflects a strategic national priority aimed at fostering economic growth and technological advancement. This emphasis has spurred extensive research and dialogue on addressing the complexities and enhancements within STEM education. The rapid expansion of educational institutions has highlighted both successes and challenges in implementing STEM programs across diverse demographics and regions [56].

Concurrently, China's ambition to lead globally in science, technology, and innovation has prompted rigorous scrutiny of its STEM education system to ensure it cultivates competitive talent. Cultural and societal dynamics unique to China profoundly influence the perception, delivery, and enhancement of STEM education, fostering a robust academic discourse on the associated challenges. Chinese researchers and educators actively contribute to this discourse through prolific publication, enriching the literature on various facets of STEM education challenges [56].

All in all, a significant portion of research (57.1% or 36 papers) has been conducted in seven developing countries (China, India, Indonesia, Malaysia, Philippines, Thailand, and Vietnam), highlighting their engagement in addressing STEM education challenges. This is encouraging as it demonstrates a growing recognition of the importance of STEM education in fostering economic development and social progress.

While developing countries play a prominent role, developed countries (Australia, Japan, New Zealand, Singapore, South Korea, and Taiwan) also contribute to the research landscape with 21 papers (33.3%) published in total. The remaining six papers (9.5%) are conducted in two least developed countries (Bangladesh and Cambodia). Ultimately, this suggests a shared interest and collaborative approach addressing STEM education challenges across the region.

Figure 4 provides a comprehensive overview of the journal distribution for research on STEM education challenges. It visually represents the articles published in each journal, allowing for a clear comparison of their contributions to the field. A significant portion of the journals, totaling 50 out of 55, have contributed only one article to the discourse on STEM education challenges. This suggests a broad-based interest in the topic, with various academic communities engaging in research and publication.

Figure 4. Publication of articles across multiple journals.

While majority of journals have published a single article, a handful of journals have made more substantial contributions. *Sustainability* stands out with four articles, suggesting that sustainability-related research is gaining substantial traction in the academic community, reflecting the growing global emphasis on sustainable development and its implications across various sectors, including education. This is followed by *Theory in Practice* with three. This indicates a strong focus and commitment to this research area within these particular journals. Besides, three journals have published two articles each: *Jurnal Pendidikan IPA Indonesia*, *International Journal of Science and Mathematics Education*, and *Education Sciences*. These journals likely play important roles in disseminating research findings and fostering discussions on STEM education challenges within their respective fields.

As presented in Table 3, the distribution of articles among the top five journals with the highest impact factors in 2023 reveals interesting trends in academic publishing. Notably, one journal, *Sustainability*, stands out with four papers among the top five, while each of the other journals (i.e., *Higher Education*, *Humanities & Social Sciences Communications, Journal of Science Education and Technology*, *and PLoS ONE*) has contributed just one paper each. The journal of *Higher Education*, which tops the list with an impact factor of 3.6, is recognized as the leading authority in the realm of higher education studies. Published by Springer, this international journal releases twelve issues annually, offering cutting-edge research and insights into the dynamics of higher education [57].

Over the decades, *Higher Education* has evolved into a critical platform disseminating significant research on educational developments across a wide spectrum of institutions, including universities, polytechnics, colleges, and vocational education institutions. The journal actively reports on developments in both public and private higher education sectors. Contributions to this journal are sourced from leading scholars globally, ensuring a diversity of perspectives and addressing a wide range of challenges faced by educators, students, planners, and administrators [57]. Given its high impact factor and the breadth of topics it covers, the *Higher Education* journal is frequently cited in academic research within the field. This frequent citation further cements its status as an essential resource for anyone engaged in higher education studies.

Apart from that, the presence of articles in journals such as *Humanities & Social Sciences Communications* (impact factor 3.5), *Journal of Science Education and Technology* and *Sustainability* (impact factor 3.3 each), and *PLoS ONE* (impact factor 2.9) indicates the interdisciplinary nature of research contributing to high-impact scholarship. Each of these journals is recognized for its focus on specific academic fields, yet they all share a common goal of advancing knowledge through rigorous peer-reviewed research.

Table 3. The top five journals with the highest impact factors (2023) and the number of articles published.

Journal	Impact Factor	No. of paper
Higher Education	3.6	1
Humanities & Social Sciences Communications	3.5	1
Journal of Science Education and Technology	3.3	1
Sustainability	3.3	4
PLoS ONE	2.9	1

Table 4 highlights a brief description of the top five papers with the most citations, which each article garnering over 90 citations by April 2024. The focus of these articles underscores the pressing challenges in STEM education, particularly within the context of secondary/high school education.

These challenges revolve around critical areas such as student soft skills, student enrolment, learning approach and teaching practices.

Table 4. The top five most cited articles (Until April 2024).

Author	Title	Journal	No. of Citations	Subject
[30]	Analysis of Students' Critical Thinking Skill of Middle School through STEM Education Project-Based Learning	Jurnal Pendidikan IPA Indonesia	449	Student soft skills in secondary/ high school
[26]	Secondary Students' Perceptions of Assessments in Science, Technology, Engineering, and Mathematics (STEM)	Eurasia Journal of Mathematics, Science and Technology Education	122	Student enrolment in secondary/high school
[31]	Enhancing Creativity and Problem-Solving Skills Through Creative Problem Solving in Teaching Mathematics	Creativity Studies	104	Student soft skills in secondary/high school
[58]	STEM Education in Secondary Schools: Teachers' Perspective towards Sustainable Development	Sustainability	104	Teaching practices in secondary/high school
[59]	Challenges in STEM Teaching: Implication for Preservice and Inservice Teacher Education Program	Theory into Practice	99	Teaching practices in secondary/high school

The most cited article [30], "Analysis of Students' Critical Thinking Skill of Middle School through STEM Education Project-Based Learning", published in *Jurnal Pendidikan IPA Indonesia*, stands out with impressive citations. We delve into the critical aspect of developing students' critical thinking skills through project-based learning within STEM education. The significant number of citations reflects the widespread recognition of the importance of fostering soft skills, such as critical thinking, which are essential for success in STEM fields.

Another highly cited article [31], with 104 citations, is "Enhancing Creativity and Problem-Solving Skills through Creative Problem-Solving in Teaching Mathematics," published in *Creativity Studies*. This paper also emphasizes the development of soft skills, particularly creativity and problem-solving, highlighting the ongoing efforts to enhance these competencies among secondary/high school students. The focus on soft skills across these studies suggests a growing consensus in the educational community about the need to prepare students not only with technical knowledge but also with the cognitive and interpersonal skills required to thrive in a rapidly evolving world.

The second most cited article [26], "Secondary Students' Perceptions of Assessments in Science, Technology, Engineering, and Mathematics (STEM)", published in the *Eurasia Journal of Mathematics, Science and Technology Education*, with 122 citations, addresses student enrolment in STEM subjects. This research explores students' perceptions of assessments within STEM education, providing insights into how assessment practices impact student engagement and retention in STEM courses. The high citation count of this article indicates the relevance of understanding and improving student enrolment and retention rates in STEM education, a critical issue for educators and policymakers alike.

In addition, two of the top five most cited articles [58,59] focus on teaching practices in STEM education, the article titled "STEM Education in Secondary Schools: Teachers' Perspectives towards Sustainable Development", published in *Sustainability*, and the article "Challenges in STEM Teaching: Implication for Preservice and Inservice Teacher Education Program", published in *Theory into Practice*, both received 104 and 99 citations, respectively. These studies underscore the importance of teaching practices in shaping the effectiveness of STEM education and highlight the role of teachers in integrating sustainable development principles into the curriculum.

The emphasis on teaching practices across these articles reflects the critical role of educators in implementing effective STEM education strategies. Moreover, the focus on sustainable development suggests a broader recognition of the need to align STEM education with global sustainability goals, preparing students to address the complex challenges of the future.

All in all, the top five most cited articles in STEM education research provide valuable insights into the key challenges and opportunities within the field. The focus on student soft skills, enrolment, learning approaches, and teaching practices reflects the multifaceted nature of STEM education and the critical need to address these areas to enhance the quality and effectiveness of STEM education at the secondary/high school levels. The high citation counts of these articles underscore their impact on the academic community and their contribution to advancing knowledge in STEM education.

5. Content analysis

A total of 63 articles on the challenges of STEM education are found in the scoping review. The 63 articles that qualified for this study are then assessed in terms of (i) the type of challenges in STEM education; (ii) the level of institution involved; and (iii) the type of challenges based on level of institution.

5.1. Types of challenges in STEM education

In response to the research question, "What types of challenges are most frequently found in relation to STEM education across the Asia-Pacific region?", this study review identifies and categorizes seven primary types of challenges (refer to Table 5), namely teaching practices, learning approach, gender disparities, and location, career interest, student enrolment, as well as student soft skill.

Teaching practices, ranked as the Top 3 challenges, emerges as the most frequently cited challenge, accounting for 30.2% of the studies (19 papers). It is related to the challenges faced by teachers/educators/instructors in teaching STEM education [11–13,58–73]. These comprise teacher's ability and preparedness to teach STEM subjects [11–13,60,61], integration of STEM disciplines applications [58,62], application of Science as a Human Endeavour (SHE) curriculum [63], Chem-A Module exposure [64], constructing a prototype cutting device for the blind [65], evidence-based teaching (EBT) [66], STEM professional learning community (STEM PLC) [67], specialized STEM teacher preparation program [59], STEM applied learning programme (ALP) [68], STEM education application related to real-world problems [69], teacher-centered instruction [70], and teachers' pedagogical involvement in the partnership project [71], and lack of teaching materials [72,73].

Moreover, learning approach stands out to be the second most prevalent challenge, with 28.6% of the studies (18 papers) highlighting issues related to how students engage with STEM learning [14–16,74–88]. This includes students' adaptability to online learning [15,74–76], difficulties with language barriers [77,78], assignment-based curriculum [79], course-related challenges [80], curriculum innovation [81], integrated STEM inquiry projects [14], integrated STEM-based program [82], lack of diagram specific skill [16], lack of interest [83], mathematical modeling activities [84], minimal 'real-life' applications [85], problem-based learning [86], robotics education [87], and STEM Education for Sustainability (STEM4S) adaptivity [88].

The third most prevalent challenge identified is gender disparities. It accounts for 15.9% of the studies with 10 papers, emphasizing the persistent gender-related challenges in STEM education [17–19,89–95]. Students faced significant challenges pertaining to gender disparities, including lower enrolment in STEM stream/course [18,89–92], unintentional preferential treatment [17], socio-cultural obstacles [93], gender-segregated education [19], lower self-perceived employability (SPE) [94], and lower pay in surgical specialties [95].

Apart from that, location [20–22,96], career interest [23–25], student enrolment [26–28,98], and student soft skills [29–31,99] indicate less frequent but significant barriers in STEM education, with each being identified in 6.3% of the studies (4 papers each).

5.2. Levels of educational institutions involved

In response to the research question, "At which levels of educational institutions are STEM challenges most commonly faced across the Asia-Pacific region?", this review reveals that the challenges in STEM education are encountered across all levels of educational institutions, as depicted in Table 5. The majority of the studies (57.1%, or 36 papers) reveal challenges faced at the secondary/high school level. This suggests that secondary school is where STEM-related challenges are most prevalent. These challenges encompass various dimensions, including teaching practices [12,13,58,59,61,62,63–65,67–69,71,73], learning approach [15,16,80,81,83–85,87], gender disparities [18,19], location [20,22–24,96], career interest [26–28], and student enrollment [29–31]. The prevalence of these challenges at this level may be due to the complexity of STEM subjects introduced during these years and the critical role of secondary education in preparing students for higher education and careers in STEM fields.

Challenges in STEM education are also significantly reported at the higher education level, accounting for 38.1% of the studies (24 papers). These challenges span multiple areas, including teaching practices [60,66,70,72], learning approach [74–79,82,86,88], gender disparities [89–95], career interest [25,97], student enrolment [98], and student enrolment [99]. This finding underscores the ongoing difficulties that students and institutions face even after secondary education.

STEM challenges at the primary school and kindergarten levels have been less frequently studied. Only two papers (3.2%) focus on primary schools, addressing teaching practices [11] and learning approach [14]. Additionally, one paper (1.6%) discusses kindergarten, specifically in relation to gender disparities [17]. This lower frequency of research may reflect the early stage of STEM curriculum integration at these levels, where the emphasis might be more on foundation skills rather than specialized STEM education.

Table 5. Type of challenges in STEM education and level of educational institution.

Author	Type of Challenges							Level of Educational Institution			
	Teaching Practices	Learning Approach	Gender Disparities	Location	Career Interest	Student Enrolment	Student Soft Skill	Kindergarten	Primary School	Secondary/High School	Higher Education
[11]	x								•		
[12]	x									•	
[69]	x									•	
[13]	x									•	
[62]	x									•	
[67]	x									•	
[58]	x									•	
[64]	x									•	
[63]	x									•	
[71]	x									•	
[59]	x									•	
[65]	x									•	
[73]	x									•	
[61]	x									•	
[68]	x									•	
[70]	x										•
[66]	x										•
[60]	x										•
[72]	x										•
[14]		x							•		
[85]		x								•	
[16]		x								•	
[15]		x								•	
[84]		x								•	
[80]		x								•	
[87]		x								•	
[83]		x								•	
[81]		x								•	
[74]		x									•
[75]		x									•
[78]		x									•
[86]		x									•
[79]		x									•
[76]		x									•

[82]		x									•
[88]		x									•
[77]		x									•
[17]			x					•			
[19]			x							•	
[18]			x							•	
[94]			x								•
[95]			x								•
[89]			x								•
[90]			x								•
[91]			x								•
[92]			x								•
[93]			x						•		•
[20]				x						•	
[21]				x						•	
[22]				x						•	
[96]				x						•	
[23]					x					•	
[24]					x					•	
[25]					x						•
[97]					x						•
[26]						x				•	
[27]						x				•	
[28]						x				•	
[98]						x					•
[29]							x			•	
[30]							x			•	
[31]							x			•	
[99]							x				•
Total	19	18	10	4	4	4	4	1	2	36	24

Note: "x" indicates the type of challenges in STEM education in the selected paper; "•" indicates the level of educational institution

5.3. Type of challenges in STEM education based on level of institution

This aligns with the number of STEM education challenges faced by educational institutions (see Table 6). In response to the research question, "What types of STEM challenges are encountered at different levels of educational institutions across the Asia-Pacific region?", this review identifies that secondary/high school face the most comprehensive range of challenges, encountering all seven distinct challenges (see Table 6). Higher education institutions contend with six types of challenges, excluding location. Moreover, primary schools face three challenges: learning approach, teaching practices, and gender disparities. Kindergarten encounters only one challenge in STEM education: Gender disparities.

Table 6. Type of challenges in STEM education based on level of educational institution.

Both	Level of Educational Institution			
Type of Challenges	Kindergarten	Primary school	Secondary school/ High School	Higher Education
Learning Approach		x	x	x
Gender Disparities	x		x	x
Teaching Practices		x	x	x
Location			x	
Career Interest			x	x
Student Enrolment			x	x
Student Soft Skill			x	x
Total	1	2	7	6

Note: "x" indicates the type of challenges in STEM education in the selected papers

There are two common challenges found in three educational institutions (primary school, secondary/high school, and higher education): Learning approach and teaching practices, while gender disparities is present in the kindergarten, secondary school/high school, and higher education. Additionally, issues related to the career interest, student enrolment, and student soft skills are shared by secondary school/high school and higher education. Learning experience is shared by primary schools and higher education institutions. Last, location of the institution is faced by secondary school/high school.

5.3.1. Challenges at three levels of educational institutions

Among the 19 papers discussing teaching practices in STEM education (refer to Table 5), the majority (14 papers; 73.7%) focus on secondary/high school [12,13,58,59,61–65,67–69,71,73], while four papers (21.1%) address higher education [60,66,70,72]. Only one paper (5.3%) examines primary school, where the identified challenge is the teacher's ability to effectively teach STEM [11]. This challenge is also encountered by secondary school teachers [12,13,61] and those in higher education [60].

For secondary schools, the challenges include applications of integrated STEM disciplines [58,62], STEM education related to real-world problems [69], development of STEM professional learning communities (STEM PLC) [67], exposure to the Chem-A Module [64], application of the Science as a Human Endeavour (SHE) curriculum [63], teachers' pedagogical involvement in partnership projects [71], specialized STEM teacher preparation programs [59], and teacher's ability and preparedness to teach STEM subjects [12,13,61]. Other issues include constructing a prototype cutting device for the blind [65] and implementing STEM applied learning programs (ALP) [68]. Additionally, teachers also encounter difficulties in developing teaching materials [73], a challenge that is also prevalent in higher education [72]. In higher education, the specific challenges also include teacher-centered instruction [70] and evidence-based teaching (EBT) [66].

Of the 18 papers reviewed on learning approaches in STEM education, nine (50.0%) have focused on higher education [74–79,82,86,91], eight (44.4%) on secondary/high school [15,16,80,81,83–85,87], and only one (5.6%) on primary school [14]. In primary school, students face challenges with integrated STEM inquiry projects [14]. Secondary/high school students, encounter issues on minimal 'real-life' applications [85], lack of diagram-specific skills [16], difficulties adapting to online learning [15], mathematical modeling activities [84], course-related challenges [80], robotics education [87], lack of interest [83], and curriculum innovation [81]. Apart from that, STEM students in higher education face challenges in adapting to online learning [74–76], language learning [77,78], problem-based learning [86], assignment-based curriculum [79], integrated STEM programs [82], and adapting STEM Education for Sustainability (STEM4S) [88].

Of the 10 papers discussed on gender disparities in STEM education (refer to Table 5), seven papers (70%) have focused on higher education [89–95], two (20%) on secondary/high school [18,19], and one (10%) on kindergarten [17]. In kindergarten, female students experience unintentional preferential treatment [17], with early childhood educators (ECEs) showing inadvertent favoritism towards boys during STEM-related play activities. Such biases can affect young girls' identity formation and contribute to the ongoing underrepresentation of women in STEM fields in the future.

Apart from that, in secondary school, female students face issues on the gender-segregated education [19], as well as a reduction in enrollment of women in STEM education [18]. Gender-segregated schooling, commonly practiced in Islamic countries, is often seen as a contributing factor. However, this issue sparks much controversy, with critics arguing that evidence is lacking, and that segregation may foster sexism and hinder social skills [19].

Interestingly, challenges related to female enrolment in STEM education continues at higher education [89–92]. Female students also face lower self-perceived employability (SPE) [94], socio-cultural obstacles [93] and lower paid surgical specialties during their internships [95].

5.3.2. Challenges at two levels of educational institutions

Of the four papers discussed on student enrollment [26–28,98], three (75%) focus on secondary school [26–28], while one (25%) addresses higher education [98]. At the secondary/high school level, challenges in student enrolment include students' perceptions of assessments in STEM-related subjects [26], leaving science-track classes [28], and the professional partnerships between teachers and academics [27]. In higher education, significant challenge includes participation patterns between humanities and STEM programs [98].

In terms of soft skills [29–31,99], three studies (75%) focus on secondary/high school [29–31] and only one paper (25%) focuses on higher education [99]. Secondary/high school students face challenges in developing creative thinking skills [29], critical thinking skills [30], and creative problem-solving [31]. In higher education, teamwork communication skills are identified as a challenge among STEM students [99].

Additionally, among the four papers addressing career interests, half (50%) focus on secondary/high school [23,24], while the other half (50%) concentrate on higher education [25,97]. Challenges related to career interests at the secondary/high school level include students' limited exposure to STEM education goals [23] and a collectivistic culture among students [24]. In higher education, attitudes [25,97], and readiness [97] towards STEM careers pose significant challenges.

5.3.3. Challenges at one level of educational institutions

All four papers highlight significant challenges faced by secondary/high schools due to their locations [20–22,96]. These challenges include difficulties in recruiting and retaining STEM teachers [20,22], issues of isolation and under-resourcing [20], and low student engagement in STEM subjects [21]. Additionally, poor achievement and aspirations among rural students pose significant concerns [20]. For example, rural students often struggle with academic performance in technology subjects [96].

6. Discussion

We attempt to systematically review the existing literature on challenges in STEM education, by practicing scoping review. A systematic search of the literature from two major academic databases, WoS and Scopus, yields 63 relevant papers for analysis. Several key insights are highlighted by the findings. Overall, the findings underscore that teaching practices, follows by learning approaches, and gender disparities are the most prominent challenges in STEM education across the Asia-Pacific region. Addressing these issues is crucial for improving STEM education outcomes at all level of educational institutions and fostering greater student engagement and success in the region.

6.1. Teaching practices

STEM educators face numerous challenges in practicing their teaching [11–13,58–73]. Our findings of this review reveal that this challenge is most pronounced at the secondary/high school [12,13,58,59,61–65,67–69,71,73], follows by higher education [60,66,70,72] and primary school [11]. The primary issue is concerning the teacher's ability and preparedness to teach STEM subjects, which being encountered in secondary/high school [12,13,61], higher education [60], and primary school [11]. In primary school, teachers often struggle with inadequate preparation and proficiency in delivering STEM education. These challenges are exacerbated by time limitations, a lack of research skills, and insufficient access to learning resources [11].

The problem persists in secondary/high school, where it becomes especially critical for novice teachers to acquire the necessary expertise to effectively teach at this level [61]. Additionally, teachers often struggle with managing a diverse student body, particularly in maintaining student focus during STEM classes. Students exhibit a wide range of knowledge about technology and its applications, making it essential for STEM projects to align not only with the curriculum but also with the varying conditions and capabilities of the students [12].

In Indonesia, for example, secondary school teachers have identified time constraints as a key factor impacting their ability to deliver effective STEM instruction. Teachers have highlighted the lack of time to prepare STEM teaching materials, along with the limited time allotted for teaching STEM within the existing curriculum that separates science and mathematics instruction [13]. Educators also report struggles with integrating multidisciplinary knowledge due to mismatched expertise, the abstract nature of certain STEM subjects, and a deficiency in foundational knowledge and teaching strategies [62]. For STEM educators, having a strong command of content knowledge is essential [100]. Without proper support and resources, educators face ongoing difficulties in delivering impactful STEM education.

Research from Malaysia mirrors these struggles, revealing that time constraints faced by teachers in preparing STEM-related materials [101] and insufficient teacher understanding [102] hinder effective STEM implementation. Similarly, in Indonesia, the main obstacles for STEM teachers are limited time and a lack of comprehensive understanding of STEM [103]. The findings are consistent with a study conducted across three Asia-Pacific countries, including Taiwan, Thailand, and Vietnam [104]. The study highlights three key challenges teachers encounter when implementing STEM practices in their classrooms: (a) insufficient knowledge of STEM, (b) challenges in integrating scientific topics with mathematics, and (c) the limited applicability of the STEM approach to certain subjects.

This issue continues at higher education, where a recurring barrier is the lack of time to prepare and deliver integrated STEM teaching, as current schedules often separate science and mathematics, reducing opportunities for cohesive STEM instruction [60]. Additionally, teachers express concerns about their ability to create meaningful learning contexts or foster a holistic understanding of STEM, due to the outdated textbooks and materials fail to engage students [72]. To address these barriers and improve the impact of STEM education, educators must adopt innovative strategies to maximize time and resources, engage students meaningfully, and foster a deeper, interdisciplinary understanding of STEM subjects.

6.2. Learning approach

The learning approach emerges as the second most common challenge, addressing issues related to student engagement in STEM learning [14–16,74–88]. Our findings of this review reveal that this challenge is most pronounced at the higher education [74–79,82,86,91], follows by secondary/high school [15,16,80,81,83–85,87] and primary school [14]. The primary issue being students' adaptability to online learning environments, which being encountered in higher education [74–76] and in secondary school [15]. On the other hand, primary school students are reported to only face challenge with integrated STEM inquiry projects [14], due to lack of foundational knowledge and limited problem-solving skills. Interestingly, this issue has also been faced by the students at higher education [82].

Adaptability to online learning is a complex, multidimensional process that requires students to navigate various challenges. It has generally been viewed unfavorably, with widespread dissatisfaction stemming from technical barriers, unstable environments, and a lack of engaging teaching methods [15,75]. At secondary/high school, these issues have notably disrupted learning outcomes, where the students face considerable difficulties with online learning, seeing it as a major departure from the traditional classroom environment in STEM education. This shift resulted in many feelings disengaged and unmotivated, with a noticeable decline in enthusiasm for learning in this format, thus, impacting the student well-being [15]. A study conducted at a secondary school in Malaysia reinforces this finding, with nearly half of the students experiencing low motivation during online learning, adversely affecting their academic performance [105]. Similarly, studies from the Philippines highlights challenges in maintaining student engagement, where majority of students struggled with concentration during online classes [106].

Apart from that, the university students face is their lack of familiarity with the digital tools and platforms essential for online education [74]. This unfamiliarity can lead to difficulties in managing coursework, participating in virtual discussions, and effectively engaging with learning materials [75]. Beyond the technical hurdles, students may also encounter challenges in adjusting their learning habits and strategies to suit the remote environment [76], further complicating the process of successful adaptation to online learning. The findings align with a study conducted at a university in Korea, which found that students' online learning experiences often fall short of expectations. The challenges stem from limited interaction with instructors, a lack of campus social engagement, insufficient technology skills, and the absence of well-structured content tailored for online courses and group activities [107].

6.3. Gender disparities

The third most prevalent challenge is gender disparities [17–19,89–95]. Findings of this review reveal that this challenge is most pronounced at the higher education [89–95], followed by secondary/high school [18,19] and kindergarten [17]. The primary issue being the enrolment of women in STEM education, which happens to be encountered at higher education [89–92] and in secondary school [18]. In kindergarten, finding shows that female students receive unintentional preferential treatment [17], where the early childhood educators (ECEs) often favor boys during STEM-related play, thus impacting girls' identity formation and contribute to their future underrepresentation in STEM fields.

Following that, in secondary school, gender disparities occur in terms of the reduction in female enrolment [18]. The study revealed a downward trend in female student enrollment at the secondary school level, particularly in digital technologies and mathematics. Previous study by Merayo and Ayuso [108] confirmed this, where it is found that fewer female students are inclined to pursue STEM fields, with many girls favoring careers in health and education, while boys tend to lean towards engineering and computer science. The main reason behind this may be due to the gender-science stereotype [109].

This downward trend contributes to the ongoing underrepresentation of women in STEM fields at the higher education level [89–95], a challenge that has become increasingly prominent in recent years. In Japan, a decline in STEM undergraduates ranks among the top three gender-related issues [89]. Moreover, in Cambodia, male students in higher education outnumber female students in STEM courses by a factor of three [90]. Research from Bangladesh reveals that structural barriers, such as entrenched gender norms and stereotypes, significantly restrict women's participation in engineering [91]. Compounding these challenges are pervasive beliefs that women are inherently less intelligent and lack the essential skills for success in STEM, whereas men are often seen as naturally suited for these fields; this further exacerbates this challenge [92].

In the broader Asia-Pacific region, the stereotype that boys and men outperform girls and women in STEM can significantly erode girls' self-confidence and self-efficacy, deterring them from pursuing STEM education. This issue has been highlighted in research by the UNDP [34], which found that such stereotypes are a major deterrent for young women in considering STEM education. Additionally, women often take longer to secure STEM jobs after graduation and typically earn lower starting salaries compared to their male counterparts, further disincentivizing women from studying STEM majors [34]. These combined factors create significant barriers to gender equality in

STEM. The persistent under-representation of girls in STEM education is a deeply entrenched issue that critically impedes progress toward achieving SDGs globally, as reported by UNESCO [110].

7. Implications and recommendations

We identify three key challenges in STEM education across the Asia-Pacific region: teaching practices, learning approaches, and gender disparities. The findings enhance our theoretical understanding of how these challenges influence STEM outcomes and offer a foundation for future research. Practically, they provide critical insights for stakeholders to develop targeted interventions, improving teaching and learning effectiveness and promoting gender inclusivity. Addressing these issues is crucial for advancing Sustainable Development Goal 4, ensuring STEM education becomes more accessible, equitable, and impactful across the region.

7.1. Teaching practices

The challenges associated with teaching practices in STEM education, especially at the secondary/high school and higher education level in the Asia-Pacific region necessitate a comprehensive and proactive approach in boosting teacher's ability and preparedness to teach STEM subjects. Educators, policymakers, and stakeholders should consider several key strategies. A critical first step in addressing these challenges is to enhance teacher training, as well-prepared and confident educators are key to effective STEM instruction. Teacher self-efficacy, or the belief in one's own ability to teach effectively, has been shown to significantly impact student outcomes. Therefore, substantial investment should be made in ongoing professional development programs specifically designed for STEM educators. These programs should focus on building teacher self-efficacy by offering training in current STEM initiatives, innovative teaching methodologies, and effective content delivery techniques. By staying updated with advancements in STEM fields and teaching practices, educators will not only be more confident in their abilities but also more capable of engaging students and promoting deep learning. Professional development should also emphasize pedagogical strategies that encourage inquiry-based learning, critical thinking, and problem-solving, which are essential components of STEM education.

Revising STEM curricula to include relevant, real-world applications is equally important for enhancing student engagement and comprehension. Traditional STEM instruction, which often focuses on abstract theories and rote learning, can be disconnected from the everyday experiences of students, making it difficult for them to see the relevance of these subjects in their lives. By integrating real-world scenarios, such as climate change, renewable energy, or technological innovations, into STEM lessons, educators can make the content more meaningful and engaging. For instance, physics lessons that explore the science behind renewable energy technologies can help students understand the role of physics in solving global challenges. Similarly, biology lessons on environmental sustainability can highlight the importance of STEM in protecting ecosystems. Involving educators in the curriculum development process is crucial to ensure that these materials are both relevant and aligned with student needs and educational goals. Teachers' input will also help create curricula that cater to diverse student populations and learning styles, ensuring a more inclusive and effective STEM education.

Providing essential resources is another cornerstone of successful STEM education. Access to up-to-date materials, tools, and technologies is critical for implementing innovative teaching methods and fostering hands-on learning experiences. To create a stimulating learning environment, it is essential that educational institutions be equipped with the latest technology and lab equipment, such as 3D printers, coding kits, robotics, and virtual reality tools. These resources not only enhance learning but also allow students to apply theoretical knowledge in practical, real-world contexts. Governments, school administrators, and stakeholders should prioritize allocating sufficient funding to ensure that schools and universities have the necessary infrastructure and resources to support effective STEM teaching. Equipping teachers with modern educational tools and materials empowers them to deliver more engaging lessons that foster creativity, innovation, and a deeper understanding of STEM subjects.

At the policy level, governments and higher education institutions must take bold steps to foster the growth of STEM education. This can be achieved by creating initiatives that not only attract skilled educators to the STEM fields but also provide incentives for retaining them. Governments can offer scholarships, financial aid, and professional development opportunities to aspiring STEM teachers, encouraging them to pursue careers in education.

7.2. Learning approach

Addressing the challenges related to learning approaches in STEM education at both secondary/high school and higher education levels in the Asia-Pacific region demands a comprehensive, innovative strategy that focuses on enhancing online learning adaptability, fostering creativity, and equipping educators to deliver effective, engaging instruction. Given the rapid shift to digital education, especially after the global pandemic, it is imperative for institutions to prioritize initiatives that improve students' adaptability to online learning environments and provide them with the skills and resources necessary to succeed.

A crucial first step in enhancing online learning adaptability is the provision of comprehensive technical support and training for students. Many students in the region face difficulties in navigating online platforms, social media, and digital tools, which can create significant barriers to learning. Educational institutions should, therefore, invest in robust technical infrastructures that not only ensure seamless access to learning resources but also offer continuous training programs to help students master digital tools. This includes tutorials on using Learning Management Systems (LMS), video conferencing platforms, and educational software tailored to STEM subjects. Ensuring that students are proficient in these tools will boost their confidence and ability to engage effectively in online learning.

Educator professional development is pivotal to ensuring the successful implementation of these strategies. Teachers must be equipped not only with the technical skills to navigate online platforms but also with the pedagogical tools to foster creativity and critical thinking in their students. This involves training in emerging technologies such as AI-powered educational tools, adaptive learning systems, and flipped classroom models, which can significantly enhance student engagement and learning outcomes. Teachers should also be encouraged to adopt differentiated instruction techniques, ensuring that their teaching methods are adaptable to diverse student needs and learning styles.

To keep students engaged in online learning environments, a combination of synchronous and asynchronous activities should be adopted. Synchronous activities, such as live lectures, virtual discussions, and real-time collaborative projects, help create a sense of community and immediacy, preventing students from feeling isolated. Moreover, asynchronous learning—such as recorded lectures, forums, and self-paced tasks—gives students the flexibility to learn at their own pace, accommodating different schedules and learning preferences. Incorporating both methods allow for a more dynamic and interactive online learning experience, keeping students motivated and engaged.

Another critical element in supporting students' adaptability to online learning is the provision of robust support systems. Institutions should implement well-structured academic advising, technical assistance, and mental health resources to support students holistically. Academic advisors play a crucial role in guiding students through course selections, offering personalized learning pathways, and monitoring progress to ensure students stay on track. Furthermore, technical support teams should be readily available to resolve any digital challenges students may face, ensuring a smooth and uninterrupted learning experience. Moreover, offering mental health resources and counseling services can help students cope with the emotional and psychological pressures that often accompany online learning environments.

7.3. Gender disparities

Addressing gender disparities in STEM education, particularly at the secondary school and higher education levels in the Asia-Pacific region, demands a comprehensive, innovative, and collaborative approach. To successfully close the gender gap and ensure more equitable participation, educational institutions, governments, and stakeholders must actively work together to implement long-term and sustainable strategies. One of the key elements in increasing female enrolment in STEM is the integration of female STEM professionals as role models. By showcasing successful women in STEM fields, young female students can envision themselves pursuing similar careers, helping to dismantle persistent gender stereotypes. Mentorship programs, where female students have the opportunity to interact with and learn from women in STEM, could greatly inspire and provide them with practical insights into the diverse career paths available within the field.

Alongside role modeling, fostering a growth mindset among female students is essential. Growth mindset practices, which emphasize the belief that abilities and intelligence can be developed through effort and persistence, should be incorporated into teaching methodologies. This practice will empower female students to challenge self-doubt, overcome obstacles, and build resilience, ultimately boosting their confidence to take on STEM subjects and thrive academically. Moreover, creating an inclusive and empowering classroom environment is critical to ensuring that all students, regardless of gender, feel supported and encouraged to participate in STEM education. Teachers and school administrators should be trained to recognize and actively challenge gender biases that may exist within the classroom. This can involve revising curricula to include gender-neutral examples and case studies, as well as promoting collaborative learning experiences that allow all students to contribute their ideas and skills equally.

Expanding the capacity of graduate programs in STEM is another pivotal strategy for addressing gender disparities in higher education. Increasing the number of available placements in STEM graduate programs will provide more opportunities for female students to advance their education and careers. This is particularly crucial in a field where higher education is often required for access to specialized and well-paid positions. Governments and educational institutions should prioritize the expansion of STEM graduate programs, ensuring they are accessible to a diverse range of students. These efforts, combined with ongoing support and resources, will not only benefit female students but also contribute to a more diverse and innovative STEM workforce, which is critical for the region's future growth and development.

8. Conclusions

STEM education is essential for realizing SDG Goal 4: inclusive and equitable quality education for all. By embedding STEM subjects throughout all levels of education, students from diverse and underrepresented backgrounds, particularly girls, gain access to transformative learning experiences. This approach fosters equity and prepares all students with the critical skills required to thrive in the 21st-century workforce. Thus, sustained investment in STEM education is pivotal for addressing future workforce needs and advancing global sustainable development. Aligned with these global priorities, this review identifies teaching practices, learning approaches, and gender disparities as the most pressing challenges facing STEM education across the Asia-Pacific region. These issues are especially prominent in secondary and higher education, where outdated teaching methodologies, rigid learning environments, and persistent gender imbalances limit STEM learning outcomes. Overcoming these obstacles is crucial, not only for improving educational achievements but also for empowering individuals with the skills to drive sustainable development and workforce innovation.

The study's impact stems from its comprehensive analysis of STEM challenges within the Asia-Pacific, offering valuable insights that extend beyond the region's context. By addressing these core issues: Teaching methods, learning strategies, and gender inclusivity, the review provides a clear roadmap for enhancing STEM outcomes, contributing to both national and global efforts to achieve SDG 4 and other relevant goals. Strengthening teaching practices is vital, as well-prepared educators with current knowledge and innovative pedagogical strategies are central to student success in STEM. Enhancing learning approaches through digital tools and real-world problem-solving also boosts student engagement and adaptability. Moreover, promoting gender inclusivity in STEM education is crucial for closing gender gaps and empowering all students, especially girls, to pursue STEM careers, fostering a more diverse and inclusive workforce.

By focusing on these key areas, the review provides a robust foundation for policymakers, educators, and institutions to take impactful steps toward improving STEM education across the Asia-Pacific and beyond. These efforts are critical for advancing the region's educational landscape while addressing broader global challenges such as workforce development, economic resilience, and sustainable growth. As STEM education continues to evolve, it will remain a key driver in shaping a more equitable and sustainable future.

9. Limitations and future research

The findings could lead to several recommendations for future research. First, future studies should focus more on understanding and evaluating the challenges of STEM education in terms of location, career interest among students, student enrolment, and student soft skills as only four studies each addressed these type challenges. Additionally, future studies should also focus on other stakeholders in educational institutions, such as teachers, lecturers, and staffs as majority of the studies focus primarily on students.

Second, thorough efforts as well as interventions should be taken into account to address the STEM challenges at the secondary/high school level, as this level faces all types of challenges identified in STEM education. Higher education institutions should also be a focus, as they faced six types of challenges, excluding location. Apart from that, more studies should be performed at other level of educational institutions, as the majority of existing research were focusing on secondary/high school and higher education. Next, there is also a need to continuously address learning approach, teaching practices as well as gender disparities, as these are the top 3 prominent challenges affecting three levels of educational institutions.

Of the 40 countries in the Asia-Pacific region, only 15 have explored the challenges in STEM education. This reveals a significant gap, particularly in the 25 remaining nations, with a focus on the least developed countries where the need for STEM education is most urgent. Addressing this gap through additional research is crucial, as STEM education plays a pivotal role in driving innovation, economic growth, and social progress.

Moreover, this review relied solely on two databases, WoS and Scopus, which may have limited the breadth of available information. Future research should incorporate additional databases such as Emerald, JSTOR, and ScienceDirect to capture a more comprehensive and diverse range of perspectives on STEM education challenges. Additionally, this scoping review focuses exclusively on the Asia-Pacific region, limiting its global relevance. To provide a more robust and globally applicable understanding, future scoping reviews should expand their scope to address STEM education challenges on a worldwide scale.

Finally, while electronic keyword searches are widely acknowledged as the best and most common method for conducting systematic analysis, supplementary search techniques are recommended for researchers to find existing research papers rather than electronic keyword searches [111,112]. Recommendations for the supplementary search techniques comprise (i) reference checking, which refers to the process of looking for additional papers in the reference list at the end of a chosen paper [111]; (ii) citation searching, which is the process of identifying potential or additional papers through the use of the citation network that surrounds an original paper [113]; and (iii) expert's consultation in case the researchers are not sure about the literature [114].

Author contributions

Fadhilah Jamaluddin: Conceptualization, Formal analysis, Resources, Writing – original draft, Writing – review and editing; Ahmad Zabidi Abdul Razak: Supervision, Writing – review and editing; Suzieleez Syrene Abdul Rahim: Conceptualization, Writing – review and editing. All authors have read and approved the final version of the manuscript for publication.

Acknowledgments

We would like to thank the constructive feedback provided by the reviewers.

Conflict of interest

The authors declare there is no conflict of interest in any part of this article.

Ethics declaration

The authors declare that the ethics committee approval was waived for the study.

References

1. Jones, M. and Smith, C., The Sustainable Development Goals and STEM education: Paradoxes and reframings. *Education and the UN Sustainable Development Goals: Praxis Within and Beyond the Classroom, 2023*, 655–672. Springer. https://doi.org/10.1007/978-981-99-3802-5_36
2. Talib, Z.A. and Baqiah, H., STEM education in Malaysia. *STEM education in Malaysia*, 2018, 9–36. Ministry of Higher Education.
3. Jamali, S.M., Ebrahim, N.A. and Jamali, F., The Role of STEM Education in Improving the Quality of Education: A Bibliometric Study. *International Journal of Technology and Design Education*, 2023, 33: 819–840. https://doi.org/10.1007/s10798-022-09762-1
4. Idris, R., Govindasamy, P., Nachiappan, S. and Bacotang, J., Revolutionizing STEM education: Unleashing the potential of STEM interest careers in Malaysia. *International Journal of Academic Research in Business and Social Sciences*, 2023. https://doi.org/10.6007/ijarbss/v13-i7/17608
5. Curriculum Development Division, *Sharing Malaysian experience in participation of girls in STEM education*. 2016, UNESCO International Bureau of Education (IBE), Geneva, Switzerland.
6. Aspin, S.H., Ali, M. and Muhammad, A.H.B., STEM education in Malaysia: A review. *Learning Science and Mathematics*, 2021.
7. Deehan, J., Danaia, L., Redshaw, S., Dealtry, L., Gersbach, K. and Bi, R., STEM in the classroom: A scoping review of emerging research on the integration of STEM education within Australian schools. *The Australian Educational Researcher*, 2024. https://doi.org/10.1007/s13384-024-00691-7
8. Buchholz, K., Which countries' students are getting most involved in STEM? *World Economic Forum (WEF)*, 2023, 20: 2023. Geneva, Switzerland.
9. WEF, *The Future of Jobs Report 2020*. 2020, World Economic Forum, Geneva, Switzerland.
10. Wen, H.J., STEM-ming the decline, in *The Star*. 2023, Star Media Group Berhad, Petaling Jaya, Malaysia.
11. Li, J., Goei, S.L. and Van Joolingen, W.R., A case study of teacher learning in enacting maker pedagogy through lesson study. *International Journal for Lesson & Learning Studies*, 2023. https://doi.org/10.1108/IJLLS-04-2023-0042
12. Arlinwibowo, J., Retnawati, H., Pradani, R.G. and Fatima, G.N., STEM implementation issues in Indonesia: Identifying the problems source and its implications. *The Qualitative Report*, 2023, 28(8): 2213–2229. https://doi.org/10.46743/2160-3715/2023.5667
13. Karpudewan, M., Krishnan, P., Ali, M.N. and Yoon Fah, L., Designing instrument to measure STEM teaching practices of Malaysian teachers. *Plos One*, 2022, 17(5): e0268509. https://doi.org/10.1371/journal.pone.0268509
14. Way, J., Preston, C. and Cartwright, K., STEM 1,2,3: Levelling up in primary schools. *Education Sciences*, 2022, 12(11): 827. https://doi.org/10.3390/educsci12110827

15. Beruin, L.C., STEM students' conceptions of online learning during COVID-19 pandemic: A phenomenographic study. *Journal of Pedagogical Research*, 2022, 6(4): 143–167. https://doi.org/10.33902/JPR.202217716
16. Manoharan, M. and Kaur, B., Mathematics teachers’ perceptions of diagrams. *International Journal of Science and Mathematics Education*, 2023, 21: 1315–1337. https://doi.org/10.1007/s10763-022-10312-3
17. Wang, S., Exploring early childhood educators’ perceptions and practices towards gender differences in STEM play: A multiple-case study in China. *Early Childhood Education Journal*, 2024, 52(6): 1121–1134. https://doi.org/10.1007/s10643-023-01499-3
18. Jaremus, F., Gore, J., Fray, L. and Prieto-Rodriguez, E., Senior secondary student participation in STEM: Beyond national statistics. *Mathematics Education Research Journal*, 2019, 31: 151–173. https://doi.org/10.1007/s13394-018-0247-5
19. Smith, A. and Evans, T., Gender gap in STEM pathways: The role of gender-segregated schooling in Mathematics and Science performance. *New Zealand Journal of Educational Studies*, 2024, 1–19. https://doi.org/10.1007/s40841-024-00320-y
20. Murphy, S., Leadership practices contributing to STEM education success at three rural Australian schools. *The Australian Educational Researcher*, 2023, 50(4): 1049–1067. https://doi.org/10.1007/s13384-022-00541-4
21. Fraser, S., Barnes, N., Kilpatrick, S., Guenther, J. and Nutton, G., Considering young people’s dislocation from STEM education: looking beyond the narrow focus of teaching and learning practice within school. *Frontiers in Education*, 2021, 6: 678613. https://doi.org/10.3389/feduc.2021.678613
22. Zhai, X., Schneider, B. and Krajcik, J., Motivating preservice physics teachers to low-socioeconomic status schools. *Physical Review Physics Education Research*, 2020, 16(2): 023102. https://doi.org/10.1103/PhysRevPhysEducRes.16.023102
23. Razali, F., Exploring crucial factors of an interest in STEM career model among secondary school students. *International Journal of Instruction*, 2021, 14(2): 385–404. https://doi.org/10.29333/iji.2021.14222a
24. Li, J., Mau, W.C.J., Chen, S.J., Lin, T.C. and Lin, T.Y., A qualitative exploration of STEM career development of high school students in Taiwan. *Journal of Career Development*, 2021, 48(2): 120–134. https://doi.org/10.1177/0894845319830525
25. Mau, W.C.J., Chen, S.J. and Lin, C.C., Social cognitive factors of science, technology, engineering, and mathematics career interests. *International Journal for Educational and Vocational Guidance*, 2021, 21: 47–60. https://doi.org/10.1007/s10775-020-09427-2
26. Meng, C.C., Idris, N. and Eu, L.K., Secondary students' perceptions of assessments in science, technology, engineering, and mathematics (STEM). *Eurasia Journal of Mathematics, Science and Technology Education*, 2014, 10(3): 219–227. https://doi.org/10.12973/eurasia.2014.1070a
27. Bissaker, K., Transforming STEM education in an innovative Australian school: The role of teachers’ and academics’ professional partnerships. *Theory Into Practice*, 2014, 53(1): 55–63. https://doi.org/10.1080/00405841.2014.862124
28. Pov, S., Kawai, N., Chey, R., Khut, S. and Kawai, N., Examining factors influencing students to leave science classes in Cambodia: A two-level hierarchical linear modeling. *Asia Pacific Education Review*, 2024, 25(1): 117–130. https://doi.org/10.1007/s12564-024-09928-7

29. Sutaphan, S. and Yuenyong, C., Enhancing grade eight students' creative thinking in the water STEM education learning unit. *Cakrawala Pendidikan*, 2023, 42(1): 120–135. https://doi.org/10.21831/cp.v42i1.36621
30. Mutakinati, L., Anwari, I. and Kumano, Y., Analysis of students' critical thinking skill of middle school through STEM education project-based learning. *Jurnal Pendidikan IPA Indonesia*, 2018, 7(1): 54–65. https://doi.org/10.15294/jpii.v7i1.10495
31. Khalid, M., Saad, S., Hamid, S.R.A., Abdullah, M.R., Ibrahim, H. and Shahrill, M., Enhancing creativity and problem-solving skills through creative problem solving in teaching mathematics. *Creativity Studies*, 2020, 13(2): 270–291. https://doi.org/10.3846/cs.2020.11027
32. Lee, M.H., Chai, C.S. and Hong, H.Y., STEM education in Asia Pacific: Challenges and development. *The Asia-Pacific Education Researcher*, 2019, 28: 1–4. https://doi.org/10.1007/s40299-018-0424-z
33. Lee, Y.F., Lee, L.S. and Nguyen, H.B.N., A comparison of STEM education status and trends in five highly competitive countries in the Asia-Pacific region. *Journal of Asian Vocational Education and Training*, 2023, 16: 2.
34. UNDP, *Women in Science, Technology, Engineering, and Mathematics (STEM) in the Asia Pacific*. 2024, UNDP Regional Bureau for Asia and the Pacific, New York, USA.
35. Karpudewan, M., Canlas, I.P. and Eilks, I., Contemporary Science education initiatives undertaken in the Asia Pacific region. *Asia Pacific Journal of Educators and Education*, 2022, 37(2): 1–2. https://doi.org/10.21315/apjee2022.37.2.1
36. Munn, Z., Peters, M.D.J., Stern, C., Tufanaru, C., McArthur, A. and Aromataris, E., Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Medical Research Methodology*, 2018, 18: 1–7. https://doi.org/10.1186/s12874-018-0611-x
37. Mak, S. and Thomas, A., Steps for conducting a scoping review. *Journal of Graduate Medical Education*, 2022, 14(5): 565–567. http://doi.org/10.4300/JGME-D-22-00621.1
38. Arksey, H. and O'Malley, L., Scoping Studies: Towards a Methodological Framework. *International Journal of Social Research Methodology*, 2005, 8(1): 19–32. https://doi.org/10.1080/1364557032000119616
39. Sucharew, H. and Macaluso, M., Methods for Research Evidence Synthesis: The Scoping Review Approach. *Journal of Hospital Medicine*, 2019, 14(7): 416–418. https://doi.org/10.12788/jhm.3248
40. Tricco, A.C., Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al., PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation. *Annals of Internal Medicine*, 2018, 169(7): 467–473. https://doi.org/10.7326/M18-0850
41. Tricco, A.C., Lillie, E., Zarin, W., O'brien, K., Colquhoun, H., Kastner, M., et al., A scoping review on the conduct and reporting of scoping reviews. *BMC Medical Research Methodology*, 2016, 16: 1–10. https://doi.org/10.1186/s12874-016-0116-4
42. Moher, D., Schulz, K.F., Simera, I. and Altman, D.G., Guidance for developers of health research reporting guidelines. *PLoS Medicine*, 2010, 7(2): e1000217. https://doi.org/10.1371/journal.pmed.1000217
43. Sierra-Correa, P.C. and Cantera Kintz, J.R., Ecosystem-based adaptation for improving coastal planning for sea-level rise: A systematic review for mangrove coasts. *Marine Policy*, 2015, 51: 385–393. https://doi.org/10.1016/j.marpol.2014.09.013

44. Pranckutė, R., Web of science (Wos) and Scopus: The titans of bibliographic information in today's academic world. *Publications*, 2021, 9(1): 12. https://doi.org/10.3390/publications9010012
45. Clarivate, Web of Science, 2021. Available from: https://clarivate.com/webofsciencegroup/solutions/web-of-science
46. Li, K., Rollins, J. and Yan, E., Web of Science use in published research and review papers 1997–2017: A selective, dynamic, cross-domain, content-based analysis. *Scientometrics*, 2018, 115(1): 1–20. https://doi.org/10.1007/s11192-017-2622-5
47. Feldner, D., Scopus now includes 90 million + content records!, 2023. Available from: https://blog.scopus.com/posts/scopus-now-includes-90-million-content-records
48. Scopus, What is Scopus review? Elsevier, 2022. Available from: https://service.elsevier.com/app/answers/detail/a_id/15534/supporthub/scopus/#tips
49. González-Albo, B. and Bordons, M., Articles vs. proceedings papers: Do they differ in research relevance and impact? A case study in the Library and Information Science field. *Journal of Informetrics*, 2016, 5(3): 369–381. https://doi.org/10.1016/j.joi.2011.01.011
50. Spraakman, S., Rodgers, T.F., Monri-Fung, H., Nowicki, A., Diamond, M.L., Passeport, E., et al., A need for standardized reporting: A scoping review of bioretention research 2000–2019. *Water (Switzerland)*, 2020, 12(11): 3122. https://doi.org/10.3390/w12113122
51. Colquhoun, H.L., Levac, D., O'Brien, K.K., Straus, S., Tricco, A.C., Perrier, L., et al., Scoping reviews: Time for clarity in definition, methods, and reporting. *Journal of Clinical Epidemiology*, 2014, 67(12): 1291–1294. https://doi.org/10.1016/j.jclinepi.2014.03.013
52. Levac, D., Colquhoun, H. and O'brien, K.K., Scoping studies: advancing the methodology. *Implementation Science*, 2010, 5: 1–9. https://doi.org/10.1186/1748-5908-5-69
53. Arksey, H. and O'Malley, L., Scoping studies: Towards a methodological framework. *International Journal of Social Research Methodology: Theory and Practice*, 2005, 8(1): 19–32. https://doi.org/10.1080/1364557032000119616
54. Stroud, D., Pennington, P., Cleaver, C., Collins, J.R. and Terry, N., A content analysis of research articles in The Journal for Specialists in Group Work: 1998-2015. *Journal for Specialists in Group Work*, 2017, 42(2): 194–210. https://doi.org/10.1080/01933922.2017.1282569
55. Dixon-Woods, M., Agarwal, S., Jones, D., Young, B. and Sutton, A., Synthesising qualitative and quantitative evidence: a review of possible methods. *Journal of Health Services Research & Policy*, 2005, 10: 45–53. https://doi.org/10.1177/135581960501000110
56. Hu, H., Development of STEM Education in China. *International Conference on Education, Humanities, and Management (ICEHUM 2022)*, 2023, 75–88. https://doi.org/10.2991/978-2-38476-040-4_8
57. Springer Nature, Higher education: Aims and scope, 2024. Available from: https://link.springer.com/journal/10734/aims-and-scope
58. Nguyen, T.P.L., Nguyen, T.H. and Tran, T.K., STEM education in secondary schools: Teachers' perspective towards sustainable development. *Sustainability*, 2020, 12(21): 8865. https://doi.org/10.3390/su12218865
59. Teo, T.W. and Ke, K.J., Challenges in STEM teaching: Implication for preservice and inservice teacher education program. *Theory into Practice*, 2014, 53(1): 18–24. https://doi.org/10.1080/00405841.2014.862116

60. Elladora, S.T., Gaylan, E.G., Taneo, J.K.B., Callanga, C.H., Becbec, J., Bercero, G.I.M.R., et al., Challenges in teaching Biotechnology in the Philippine STE program. *International Journal of Learning, Teaching and Educational Research*, 2024, 23(3): 367–389. https://doi.org/10.26803/ijlter.23.3.18
61. Song, H. and Zhou, M., STEM teachers’ preparation, Teaching beliefs, and perceived teaching competence: A Multigroup Structural Equation approach. *Journal of Science Education and Technology*, 2021, 30: 394–407. https://doi.org/10.1007/s10956-020-09881-1
62. Lyu, Q., Chiang, F.K. and Davis, J., Primary and middle school teacher experiences of integrated STEM education in China: Challenges and opportunities. *International Journal of Engineering Education*, 2022, 38(2): 491–504.
63. Paige, K. and Hardy, G., Science as human endeavour, critical pedagogy and practitioner inquiry: Three early career cases. *International Journal of Science and Mathematics Education*, 2019, 17(4): 679–699. https://doi.org/10.1007/s10763-018-9887-x
64. Samat, N.A.A., Chem-A Module Based on STEM approach in chemical bonding. *International Journal of Recent Technology and Engineering*, 2019, 7: 700–710.
65. Teo, T.W., Tan, A.L. and Choy, B.H., “It feels different when blindfolded”: Developing social empathy through inclusive designs in STEM. *STEM Education*, 2024, 4(1): 20–34. https://doi.org/10.3934/steme.2024002
66. Fendos, J., Why a grassroots Summer Institutes model failed: Exploring obstacles to evidence-based teaching awareness in low-awareness, low-support contexts. *Biochemistry and Molecular Biology Education*, 2020, 48(2): 143–155. https://doi.org/10.1002/bmb.21325
67. Vasinayanuwatana, T., Teo, T.W. and Ketsing, J., Shura-infused STEM professional learning community in an Islamic School in Thailand. *Cultural Studies of Science Education*, 2021, 16: 109–139. https://doi.org/10.1007/s11422-020-09990-8
68. Wen, Y., Wu, L. and He, S., Investigating affordances and tensions in STEM applied learning programme from practitioners’ sensemaking. *Educational Technology & Society*, 2021, 24(4): 99–109. https://www.jstor.org/stable/48629248
69. Tuong, H.A., Nam, P.S., Hau, N.H., Tien, V.T.B., Lavicza, Z. and Hougton, T., Utilising stem-based practices to enhance mathematics teaching in Vietnam: Developing students’ real-world problem solving and 21st century skills. *Journal of Technology and Science Education*, 2023, 13(1): 73–91. https://doi.org/10.3926/jotse.1790
70. Lin, X., Luan, L. and Dai, Y., Exploring Chinese STEM college students’ expectations of effective online courses. *International Journal of Chinese Education*, 2023, 12(2): 2212585X231188977. https://doi.org/10.1177/2212585X231188977
71. Ng, W. and Fergusson, J., Technology-Enhanced Science Partnership Initiative: Impact on secondary Science teachers. *Res Sci Educ*, 2019, 49: 219–242. https://doi.org/10.1007/s11165-017-9619-1
72. John, D. and Devi, G.S., Designing STEM-specific student-friendly reading content for the Engineering English classroom. *IEEE Transactions on Professional Communication*, 2021, 64(4): 444–455. https://doi.org/10.1109/TPC.2021.3110419
73. Hakim, A., Efwinda, S., Damayanti, P., Syam, M., Mutmainah, O. and Norsaputra, A., Improving climate literacy of high school students through physics teaching materials based on STEM. *Jurnal Pendidikan IPA Indonesia*, 2023, 12(4). https://doi.org.10.15294/jpii.v12i4.43188

74. Li, Z., Lou, X., Chen, M., Li, S., Lv, C., Song, S., et al., Students’ online learning adaptability and their continuous usage intention across different disciplines. *Humanities and Social Sciences Communications*, 2023, 10: 838. https://doi.org/10.1057/s41599-023-02376-5
75. Amantha Kumar, J. and Al-Samarraie, H., An investigation of Novice pre-university students’ views towards MOOCs: The Case of Malaysia. *The Reference Librarian*, 2019, 60(2): 134–147. https://doi.org/10.1080/02763877.2019.1572572
76. Shidiq, A.S., Permanasari, A., Hernani, H. and Hendayana, S., Contemporary hybrid laboratory pedagogy: Construction of a simple spectrophotometer with STEM project-based learning to introduce systems thinking skills. *Asia Pacific Journal of Educators and Education*, 2022, 37(2): 107–146. https://doi.org/10.21315/apjee2022.37.2.6
77. Ghulamuddin, N.J.A., Tengku Sharif, T.I.S. and Rahman, Z.A., STEM students’ English language learning strategies and underlying factors pertaining to Open Distance Learning. *Journal of Nusantara Studies (JONUS)*, 2022, 7(2): 81–102. https://doi.org/10.24200/jonus.vol7iss2pp81-102
78. Thongsri, N., Shen, L. and Yukun, B., "Does Academic Major Matter in Mobile Assisted Language Learning? A Quasi-Experimental Study", *International Journal of Information and Learning Technology*, 2019, 36(1): 21–37. https://doi.org/10.1108/IJILT-05-2018-0043
79. Yang, K., Guo, C. Y. and Glaser, R.E., Challenges of Globalization and Successful Adaptation Strategies in Implementing a “Scientific Writing and Authoring” Course in China. *Journal of Chemical Education*, 2018, 95(12): 2155–2163. https://doi.org/10.1021/acs.jchemed.8b00384
80. Rogayan Jr, D.V., Rafanan, R.J.L. and De Guzman, C.Y., Challenges in STEM learning: A case of Filipino high school students. *Jurnal Penelitian dan Pembelajaran IPA*, 2021, 7(2): 232–244. https://dx.doi.org/10.30870/jppi.v7i2.11293
81. Tan, A.L. and Leong, W.F., Mapping curriculum innovation in STEM schools to assessment requirements: Tensions and dilemmas. *Theory Into Practice*, 2014, 53(1): 11–17. https://doi.org//10.1080/00405841.2014.862113
82. Shahidullah, K. and Hossain, R., Designing an Integrated Undergraduate Disaster STEM curriculum. *Journal of Ethnic and Cultural Studies*, 2022, 9(1): 265–280. https://doi.org/10.29333/ejecs/1042
83. Gopal, K., Salim, N.R. and Ayub, A.F.M., Perceptions of learning mathematics among lower secondary students in Malaysia: Study on students' engagement using Fuzzy Conjoint Analysis. *Malaysian Journal of Mathematical Sciences*, 2019, 13(2): 165–185.
84. Lo, C.K., Huang, X. and Cheung, K.L., Toward a design framework for mathematical modeling activities: An analysis of official exemplars in Hong Kong mathematics education. *Sustainability*, 2022, 14(15): 9757. https://doi.org/10.3390/su14159757
85. Jones, M., Geiger, V., Falloon, G., Fraser, S., Beswick, K., Holland-Twining, B., et al., Learning contexts and visions for STEM in schools. *International Journal of Science Education*, 2024, 1–21. https://doi.org/10.1080/09500693.2024.2323032
86. Matawali, A., Bakri, S.N.S., Jumat, N.R., Ismail, I.H., Arshad, S.E., and Din, W.A., The preliminary study on Inverted Problem-Based Learning in Biology among Science foundation students. *International Journal of Evaluation and Research in Education*, 2019, 8(4): 713–718. http://doi.org/10.11591/ijere.v8i4.20294

87. Galino, J.R. and Tanaka, H., Initiatives and development of secondary school robotics education in Camarin high school. *Journal of Robotics Networking and Artificial Life*, 2021, 8(1): 60–65. https://doi.org/10.2991/jrnal.k.210521.014
88. Chan, M.N. and Nagatomo, D., Study of STEM for sustainability in design education: Framework for student learning and outcomes with design for a disaster project. *Sustainability*, 2021, 14(1): 312. https://doi.org/10.3390/su14010312
89. Hori, R.S., Progress and problems of gender equality in Japanese academics and geosciences. *Advances in Geosciences*, 2020, 53, 195–203. https://doi.org/10.5194/adgeo-53-195-2020
90. Perez-Felkner, L., Felkner, J.S., Nix, S. and Magalhães, M., The puzzling relationship between international development and gender equity: The case of STEM postsecondary education in Cambodia. *International Journal of Educational Development*, 2020, 72: 102102. https://doi.org/10.1016/j.ijedudev.2019.102102
91. Islam, N. and Jirattikorn, A., Navigating structural constraints: Women's agency in engineering studies and teaching in Bangladesh. *Higher Education*, 2024, 1–17. https://doi.org/10.1007/s10734-023-01177-8
92. Ahmed, N., Chowdhury, A.M., Urmi, T. and Jamal, L., Impact of socio-economic factors on female students' enrollments in Science, Technology, Engineering and Mathematics and workplace challenges in Bangladesh. *American Behavioral Scientist*, 2023, 67(9): 1104–1121. https://doi.org/10.1177/00027642221078517
93. Islam, N. and Jirattikorn, A., Breaking gender barriers in STEM education for achieving the SDG of quality education in Bangladesh. *Development in Practice*, 2023, 34(1): 129–135. https://doi.org/10.1080/09614524.2023.2229965
94. Wen, W., Zhou, L., Hu, D., Zhang, M., Yan, Z. and Tang, X., The impact of college experience on female students' self-perceived employability in STEM majors. *Frontiers in Psychology*, 2023, 14: 1282934. https://doi.org/10.3389/fpsyg.2023.1282934
95. Shao, X. and Wang, T., Grey's Anatomy: Gender differences in specialty choice for medical students in China. *Sustainability*, 2021, 14(1): 230. https://doi.org/10.3390/su14010230
96. Murphy, S., Participation and achievement in technology education: the impact of school location and socioeconomic status on senior secondary technology studies. *International Journal of Technology and Design Education*, 2020, 30: 349–366. https://doi.org/10.1007/s10798-019-09499-4
97. Rezayat, F. and Sheu, M., Attitude and readiness for STEM education and careers: A comparison between American and Chinese students, *International Journal of Educational Management*, 2020, 34(1): 111–126. https://doi.org/10.1108/IJEM-07-2018-0200
98. Chang, D.F., Zhu, W.S. and Wu, S.J., Predicting the enrollments in humanities and STEM programs in higher education using ARIMAX models. *International Journal of Online Pedagogy and Course Design (IJOPCD)*, 2022, 12(4): 1–15. https://doi.org/10.4018/IJOPCD.311435
99. Van Horne, C. and Rakedzon, T., Teamwork Made in China: Soft skill development with a side of friendship in the STEM classroom. *Education Sciences*, 2024, 14(3): 248. https://doi.org/10.3390/educsci14030248
100. Aslam, S., Alghamdi, A.A., Abid, N. and Kumar, T., Challenges in implementing STEM education: Insights from novice STEM teachers in developing countries. *Sustainability*, 2023, 15(19): 14455. https://doi.org/10.3390/su151914455

101. Baskaran, I.L. and Abdullah, O., Constraints and challenges of STEM education in Manjung district's secondary schools. *International Journal of Management Studies and Social Science Research*, 2023, 1(2): 22–44. https://doi.org/10.56293/IJMSSSR.2022.4679
102. Ramli, N.F. and Talib, O., Can education institution implement STEM? From Malaysian teacher's view. *International Journal of Academic Research in Business and Social Sciences*, 2017, 7(3): 721–732. https://doi.org/10.6007/IJARBSS/v7-i3/2772
103. Diana, N., Analysis of Teachers' Difficulties in Implementing STEM Approach in Learning: A Study Literature. *Journal of Physics: Conference Series*, 2020, 1806(1): 012219. https://doi.org/10.1088/1742-6596/1806/1/012219
104. Wahono, B. and Chang, C.Y., Assessing teacher's attitude, knowledge, and application (AKA) on STEM: An effort to foster the Sustainable Development of STEM education. *Sustainability*, 2019, 11(4): 950 https://doi.org/10.3390/su11040950
105. Basar, Z.M., Mansor, A.N., Jamaludin, K.A. and Alias, B.S., The effectiveness and challenges of online learning for secondary school students–A case study. *Asian Journal of University Education*, 2021, 17(3): 119–129. https://doi.org/10.24191/ajue.v17i3.14514
106. Vallespin, M.R. and Maricar, P., Perception of STEM Students in an Online Learning During the COVID-19 Pandemic: Advantages, Academic Challenges, and Solutions. *Iconic Research and Engineering Journals*, 2023, 6(7): 78–86. http://dx.doi.org/10.2139/ssrn.4397421
107. Xia, Y., Hu, Y., Wu, C., Yang, L. and Lei, M., Challenges of online learning amid the COVID-19: College students' perspective. *Frontiers in psychology*, 2022, 13: 1037311. https://doi.org/10.3389/fpsyg.2022.1037311
108. Merayo, N. and Ayuso, A., Analysis of barriers, supports and gender gap in the choice of STEM studies in secondary education. *International Journal of Technology and Design Education*, 2023, 33(4): 1471–1498. https://doi.org/10.1007/s10798-022-09776-9
109. Makarova, E., Aeschlimann, B. and Herzog, W., The gender gap in STEM fields: The impact of the gender stereotype of math and science on secondary students' career aspirations. *Frontiers in Education*, 2019, 4: 60. https://doi.org/10.3389/feduc.2019.00060
110. Chavatzia, T., *Cracking the code: Girls' and women's education in science, technology, engineering and mathematics (STEM)*, 2017, United Nations Educational, Scientific and Cultural Organization, Paris, France.
111. Horsley, T., Dingwall, O. and Sampson, M., Checking reference lists to find additional studies for systematic reviews. *Cochrane Database of Systematic Reviews*, 2011, 8. https://doi.org/10.1002/14651858.MR000026.pub2
112. Tsafnat, G., Glasziou, P., Choong, M.K., Dunn, A., Galgani, F. and Coiera, E., Systematic review automation technologies. *Systematic Reviews*, 2014, 3: 1–15. https://doi.org/10.1186/2046-4053-3-74
113. Briscoe, S., Bethel, A. and Rogers, M., Conduct and reporting of citation searching in Cochrane systematic reviews: A cross-sectional study. *Research Synthesis Methods*, 2020, 11(2): 169–180. https://doi.org/10.1002/jrsm.1355
114. Gøtzsche, P.C. and Ioannidis, J.P.A., Content area experts as authors: Helpful or harmful for systematic reviews and meta-analyses? *BMJ (Online)*, 2012, 345: e7031. https://doi.org/10.1136/bmj.e7031

Author's biography

Fadhilah Jamaluddin is a PhD student at Faculty of Education, Universiti Malaya, Malaysia. She is specialized in quantitative analysis, Markov Chains, Business Mathematics, STEM education, and educational leadership. Her research interests include Markov Chain model, STEM education, educational leadership and leadership psychology. She is a member of Royal Statistical Society as well as a member of Malaysian Mathematics and Sciences Association (PERSAMA).

Prof. Dr. Ahmad Zabidi Abdul Razak is a professor of education at Faculty of Education, Universiti Malaya, Malaysia. He is currently the Dean of the faculty. He is specialized in education policy, management and administration. His research interests include educational management and leadership, human resources in educational management, personal leadership and organization, educational management from Islamic perspective, and school effectiveness. He is an associate member of the National Professors Council (MPN) and a member of Honorary Members.

Dr. Suzieleez Syrene Abdul Rahman is a senior lecturer of Mathematics and Science education with Faculty of Education, Universiti Malaya, Malaysia. She is specialized in STEM education. Her research interests include Mathematics education, assessment, beliefs, qualitative research, teacher development. She is a member of Malaysia Association of Research and Education for Educators (MAsREE).