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EDITORIAL **Open Access**

A decade of research contributions and emerging trends in the *International Journal of STEM Education*

Thomas K. F. Chiu[1], Yeping Li[2*], Meixia Ding[3], Jonas Hallström[4] and Milo D. Koretsky[5]

Abstract

In this editorial, we review 400 articles and reviews published in the *International Journal of STEM Education* during its first decade (2014–2023). Using bibliometric analysis, we examine these publications to assess the journal's major contributions to STEM education research and identify emerging trends over the years. The results present a dynamic picture of the growth of STEM education, highlighting key topics, such as STEM integration, equity, and emerging technologies. These findings also reveal evolving "hot topics" that reflect the shifting interests of researchers in the field. This review suggests that many areas of STEM education research are still in the growth phase. We encourage readers to use these insights as a foundation for developing future research agendas and advancing STEM education globally.

Keywords Bibliometric analysis, Impact, Review, STEM education research, STEM integration, Technology, Trends

Introduction

The *International Journal of STEM Education* was established in 2014 to advance multidisciplinary STEM (science, technology, engineering, and mathematics) education and research (Li, 2014). Its articles make a significant impact on STEM Education researchers and practitioners worldwide as evidenced by a systematic review of the journal's publications during its first five years (2014–2018) (Li et al., 2019). This earlier review identified the most popular and emerging research topics within the field from a list of seven research areas:

1. Policy, curriculum, evaluation, and assessment in STEM education (including literature reviews about the field in general).
2. K-12 teaching, teacher, and teacher education in STEM (including both pre-service and in-service teacher education).
3. K-12 STEM learner, learning, and learning environment.
4. Post-secondary teaching and teacher in STEM (including faculty development, etc.).
5. Post-secondary STEM learner, learning, and learning environments (excluding pre-service teacher education).
6. Cultural, social, and gender issues in STEM education.
7. History, epistemology, and perspectives about STEM and STEM education.

Among these topic areas, the first three were the most frequently covered in terms of publication volume. The review highlighted that "policy, curriculum, evaluation, and assessment in STEM education" was the topic area with the highest number of highly cited publications, while the most accessed articles focused on K-12 STEM education, specifically the second and third topic areas. The overall findings revealed a wide range of published

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*Correspondence:
Yeping Li
yepingli@tamu.edu
[1] The Chinese University of Hong Kong, Hong Kong SAR, China
[2] Texas A&M University, College Station, TX, USA
[3] Temple University, Philadelphia, PA, USA
[4] Linköping University, Linköping, Sweden
[5] Tufts University, Boston, MA, USA

research, and that STEM education research and practice are still undergoing tremendous development.

With the completion of the journal's first decade of publications (2014–2023), a recent editorial summarized its development in terms of key milestones, citations, and access performance over the years (Li, 2024). During the second five-year period (2019–2023), the journal saw a dramatic increase in both publications and performance. As a leading research journal in STEM education since 2019 (Li, 2019), a detailed analysis of its publications offers valuable insights into the evolution of STEM education research. Specifically, this review aims to investigate how the *International Journal of STEM Education* informs our STEM education research communities by achieving the following goals: (1) summarize the journal's publications over its first ten years (2014–2023); (2) explore the journal's main contributions to the development of STEM education research (e.g., key topic areas); and (3) identify emerging trends in STEM education research over the past decade.

Methods

STEM education is a broad field that encompasses science education, mathematics education, engineering education, technology education, integrated STEM education, emerging technologies, and psychology. Bibliometric analysis is particularly useful for large, multidisciplinary research areas (Donthu et al., 2021), and it is well-suited for this review for three key reasons. First, it allows for the summary and the identification of numerous subfields within a broader research area by analyzing large datasets without cognitive limitations (Pellegrini et al., 2020). Second, it uncovers research structures rooted in quantitative methods (Zupic & Čater, 2015). Third, it helps identify major research topics, reveal their overarching structure, and explore emerging or declining areas (Donthu et al., 2021).

To achieve our research goals, we used bibliometric analysis to examine the journal's publications. Various techniques are available for bibliometric analysis (Donthu et al., 2021; Marín-Marín et al., 2021). We adopted a popular and reliable method, the Bibliometrix R package with the Biblioshiny application, as the primary approach for our analysis (Aria & Cuccurullo, 2017). We retrieved articles published in the *International Journal of STEM Education* from 2014 to 2023 using the Web of Science database. This database includes five types of publications: article, review, editorial material, correction, and letter. A total of 448 publications were retrieved. After removing editorial materials, corrections, and letters, 400 papers (articles and reviews) remained for analysis. For clarity, in the following sections, the term "paper" refers to the articles and reviews classified in the Web of Science database, with "article" denoting original research studies and "review" referring to review studies.

Table 1 presents a summary of the main analyses employed in this study, along with brief explanations. For Goal 1, we conducted a descriptive analysis to summarize the papers in the journal based on the number of papers, authorships, and topics. For Goals 2 and 3, we employed science mapping, specifically thematic mapping (e.g., co-occurrence analysis) and historiography mapping (Zupic & Čater, 2015). In the thematic mapping, we used co-occurrence analysis, also known as co-word analysis, to examine the relationships between keywords that provide insights into the organization of a research topic (Zupic & Čater, 2015). To visualize these results, we used a thematic map to cluster research topics into four key themes (Aria & Cuccurullo, 2017). Another key analysis was historiography, which illustrates the connections between significant individual papers over a certain time period based on citations and references to other papers. Together, these two analyses, thematic mapping and historiography, helped identify the journal's primary contributions to STEM education. Keywords and citations worked in tandem to validate the analysis.

To prepare the data for this analysis, we excluded certain terms related to research methods (e.g., systematic

Table 1 Main analyses and their description in this study

Main analyses	Description
Descriptive analysis (goal 1)	
Papers per year	Analysis of the number of papers over time to track the development of STEM education research field
Country contributions and collaboration	Analysis of country production over time and collaboration (based on co-authorships)
Popular research topics and trends	Analysis of the popular topics (based on frequency) and their trends
Top contributing papers	Analysis of the top 10 most influential papers (based on total citations and total citations per year)
Science mapping (goals 2 and 3)	
Thematic mapping	Analysis of the thematic clusters based on the keywords and their co-occurrences
Historiographic mapping	Analysis of the most influential papers based on a citation network and presentation over time

literature review, thematic analysis) to improve relevance as our focus did not include analysis of the methodological approaches used in the papers. Additionally, we applied a list of synonyms to ensure accurate topic categorization. For example, terms like “online learning,” “online learning communities,” “e-learning,” and “Moodle” were all grouped under the broad topic of “online learning.”

Results

Overview of papers and authorships (Goal 1)

This review examines 400 papers published between 2014 and 2023, consisting of 365 articles and 35 reviews. A total of 1,345 authors contributed to these papers, with an average citation count of 17.74 per paper. Figure 1 shows the number of papers published annually. The number of papers per year increased from 10 in 2014 to 62 in 2023, reflecting an average annual growth rate of 22.47%. This growth indicates not only the rapid expansion of STEM education research but also the increasing visibility of the journal, with more researchers choosing to publish in this journal, as noted in other reviews (e.g., Li et al., 2020a).

Furthermore, the results show that the top five regions in terms of paper production over time are Australia, mainland China, Germany, the United Kingdom, and the USA. The majority of authors are based in mainland China and the USA, with both countries experiencing the most significant growth in author contributions over the decade. Additionally, our analysis reveals that the rate of cross-country co-authorship is 14.75%, and the number of cross-country co-authorships per paper is 4.08. The most frequent collaborations are between mainland China and the USA, followed by partnerships between Australia and mainland China, and between South Korea and the USA. The regional classifications are based on the Web of Science database.

Popular topics and their trends (Goal 1)

Figure 2 and Table 2 present word clouds and the frequency of keywords found in the 400 papers. The research area of equity appears most frequently, with 61 occurrences. Other topics with more than 30 occurrences include integration (49), science (47), higher education (46), professional development (43), and reform (35). These areas (i) echo the primary objective of the journal to advance multidisciplinary STEM education and research (Li, 2014); (ii) are diverse, covering a range of topics, such as student learning (e.g., STEM literacy and career), psychology (e.g., belief, motivation), emerging technologies (e.g., AI and online learning), and instrument development; and (iii) are important to both K–12 and higher education.

The trend in research areas over time is shown in Fig. 3. From 2014 to 2019, the focus was on student learning and evidence-based approaches in STEM. Between 2019 and 2021, the emphasis shifted toward teacher development and educational reform in STEM

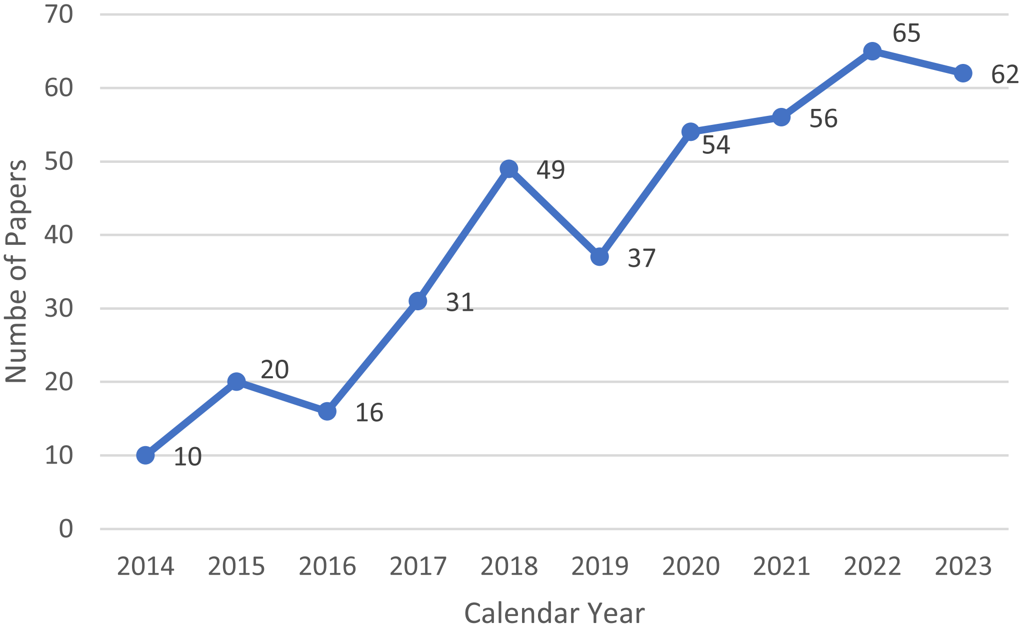

Fig. 1 The number of papers per calendar year

Fig. 2 Word clouds of the research areas

Table 2 Most frequent research areas

Research areas	Occurrences	Research areas	Occurrences
Equity	61	Motivation	23
Integration	49	Engineering	20
Science	47	Student learning	20
Higher education	46	21 century skills	14
Professional development	43	Belief	14
Reform	35	Assessment	12
School education	29	Online learning	11
Career	27	STEM literacy	10
Instructional designs	26	AI	9
Mathematics	24	Computational thinking	8

education. In 2021, psychological topics began to appear more frequently in the papers. From 2021 to 2023, there was an increasing focus on issues of equity and integration in STEM education. In 2023, an added popular topic was computational thinking.

These results suggest that early in the decade, research topics shifted from student learning to teacher development and institution reforms. This could be because findings related to student learning provided evidence for improving teaching practices and curricula. Another possibility is that funding priorities shifted over time (e.g., Li et al., 2020b). In the middle phase of the decade, personal and social issues gained prominence, such as how to integrate different disciplines (e.g., interdisciplinary approaches) and address equity issues (e.g., gender differences). In the most recent phase, emerging topics like computational thinking and AI (see Table 2) have gained traction.

Additionally, among the four major STEM research areas, science is the only one that appears in trending topics. This may suggest STEM education is often led or dominated by the science education field as observed in other literature reviews (Li et al., 2022).

Top 10 most-cited papers and their research areas in STEM education (Goal 1)

The papers published earlier tend to accumulate more citations over time. To identify important papers published in the journal, this study used both total citations and total citations per year. Additionally, we mapped the papers to the research areas identified in Table 2 to understand which areas draw scholars' attention. Table 3 provides an overview of the top 10 most-cited papers,

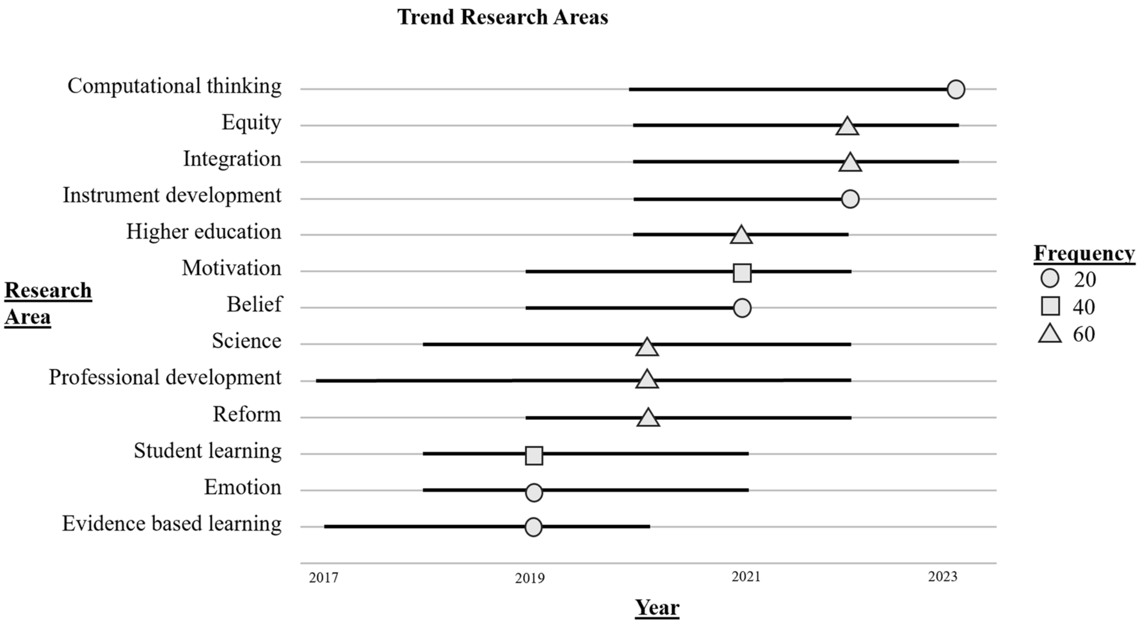

Fig. 3 Trend in research areas

ranked by total citations (TC). These papers span several key areas: teacher development (Margot & Kettler, 2019; Shernoff et al., 2017), teacher beliefs (Lund & Stains, 2015; Margot & Kettler, 2019), teaching and learning (Cooper et al., 2018; Tharayil et al., 2018), career inspiration (Blotnicky et al., 2018; Vincent-Ruz & Schunn, 2018), reforms (Shadle et al., 2017), and equity issues (Rainey et al., 2018).

Table 3 also lists the top 10 papers based on total citations per year (TCP) which highlights four recent papers published between 2020 and 2022 (see the last four rows in Table 3). Notably, Gamage et al. (2022) ranks fourth using total citations per year (TCP) and introduces a new topic: online learning. This topic is not covered by the other top 10 most cited papers, which could be a reflection of the growing impact of the COVID-19 pandemic. This implies that more research related to online learning in STEM education emerged after 2022. The remaining papers in this category focus on equity issues, career inspiration, and reforms (Kricorian et al., 2020; Reinholz & Andrews, 2020). These findings may suggest a surge in research activity in these three areas after 2020.

Based on this initial analysis of the leading papers (according to total citations) in STEM education research, we note that teacher education, future workforce, educational reforms, and equity have been key areas of focus. A plausible explanation for the higher citation rates in these areas is the growing recognition that STEM education must evolve to prepare the future workforce (Reinholz & Andrews, 2020; Shadle et al., 2017). Teachers play a crucial role in driving these changes. Their professional development not only influences the effectiveness of teaching and learning but also addresses equity concerns, such as inclusivity and diversity.

Themes and their relationships (Goal 2)

We use co-occurrence networks of the authors' keywords and thematic maps to explore how various themes in STEM education research connect to each other and their research position (e.g., motor, basic, niche, or emerging/declining). These maps also help identify topics within a theme. The following presents an overview of all clusters/themes, along with nine main clusters/themes identified in the thematic map.

Figure 4 shows the overall co-occurrence network of the authors' keywords (Note: node size reflects the number of occurrences, and ties represent the number of co-occurrences.). The network identifies integration, science, equity, career, reform, instructional designs, school, and higher education as the main clusters/themes. Within this network, there are many sub-networks represented by different colors. The sub-networks provide us with five main results: (i) current research in STEM education is predominantly guided by science; (ii) implementing an integrative approach in STEM necessitates reform in institutions and curriculum; (iii) equity in STEM is linked to mentoring, fostering a sense of belonging, and retention; (iv) career paths in STEM are influenced by motivation; and (v) STEM holds significance in both K-12 and higher education.

Table 3 An overview of the top 10 articles sorted by total citations (TC) and total citations per year (TCP), respectively

Paper	Year/types	TC/Rank	TCP/Rank	Keywords	Research areas (see Table 2)
Margot KC	2019/ Review	261/1	43.50/1	STEM, Teacher perception, Teacher beliefs, Systematic literature review, Engineering in K-12 schools	Belief, Engineering, School education, Professional development
Rainey K	2018/ Article	224/2	32.00/2	Gender, Race, Belonging, Intersectional Retention, Representation	Equity
Li YP	2020/ Review	140/3	28.00/3	Journal publication, Literature review, Status, STEM education research, Trends	Science, Mathematics, Engineering
Lund TJ	2015/ Article	123/4	12.30/NA	Student-centered teaching, Evidence-based instructional practices, Physics, Chemistry, Biology, Diffusion of innovation, Beliefs about teaching, Contextual factors, Research-intensive institution	Belief, Science, Student learning, Higher education
Shernoff DJ	2017/ Article	115/5	14.38/9	STEM education, STEM disciplines, STEM teacher, STEM subjects	Professional development
Cooper KM	2018/ Article	105/6	15.00/5	Mental health, Anxiety, Anxiousness, Stress, Active learning, Evaluation, Fear of negative evaluation, Clickers, Group work, Cold call, Random call, Science classroom, College classroom, Undergraduates	Higher education, Student learning
Vincent-Ruz P	2018/ Article	101/7	14.43/7	Scientific identity, Student choice, Early high school, Crucial developmental period, Optical sciences	Career, School education
Shadle SE	2017/ Article	97/8	12.13/NA	Barriers to change, Drivers to change, STEM education reform, Evidence-based instructional practices, Departmental differences	Reform, Integration
Blotnicky KA	2018/ Article	89/9	12.71/NA	STEM career, Mathematics self-efficacy, Technical skills, Career knowledge, Career awareness, Career interests, Career activities, Education, Subject requirements	Career
Tharayil S	2018/ Article	89/10	12.71/NA	Active learning, Student resistance, Instructional strategies, Undergraduate engineering	Higher education, Instructional designs, Student learning
Gamage SHPW	2022/ Review	49/NA	16.33/4	Moodle, Learning management systems, Education, e-learning, Thematic analysis	Online learning
Marin-Marin JA	2021/ Review	58/NA	14.50/6	STEAM, SciMAT, Education, Bibliometrics	Science, Mathematics, Engineering
Kricorian K	2020/ Article	72/NA	14.40/8	Mentoring, Media models, Ethnicity, Gender, Representation, Belonging, Identity, Mindsets, STEM	Equity, Career
Reinholz DL	2020/ Article	70/NA	14.00/10	Change, Reform, Theory of change, Change theory, Education reform, Undergraduate STEM	Reform, Higher education

In addition to the co-occurrence network, this study also used a thematic map to examine the position of clusters/themes based on their relevance and development degrees. The map categorizes clusters/themes into four main theme groups: motor, basic, niche, and emerging/declining. These clusters are organized along two axes: the X-axis represents the relevance of a topic (relevance degree), while the Y-axis indicates its stage of development (development degree) (see Fig. 5) (Cobo et al., 2011; Kaiser & Kuckertz, 2023). Motor themes are highly developed, central, and driving forces in a research field. Basic themes, though underdeveloped, are equally important. Niche themes are well-developed but isolated or less relevant to the core concerns of the field. Emerging or declining themes are less developed and have marginal significance, though they may become important or fade in relevance over time (Marín-Marín et al., 2021).

Figure 5 shows a thematic map of authors' keywords, featuring nine main clusters/themes: integration, equity, mathematics, motivation, belief, AI, emotion, online learning, and computational thinking. These clusters/themes are classified into four main theme groups: motor themes (top right), basic themes (bottom right), niche themes (top left), and emerging or declining themes (bottom left). The size of each cluster/theme circle reflects its ability to represent sub-themes and their interrelationships within the network. To

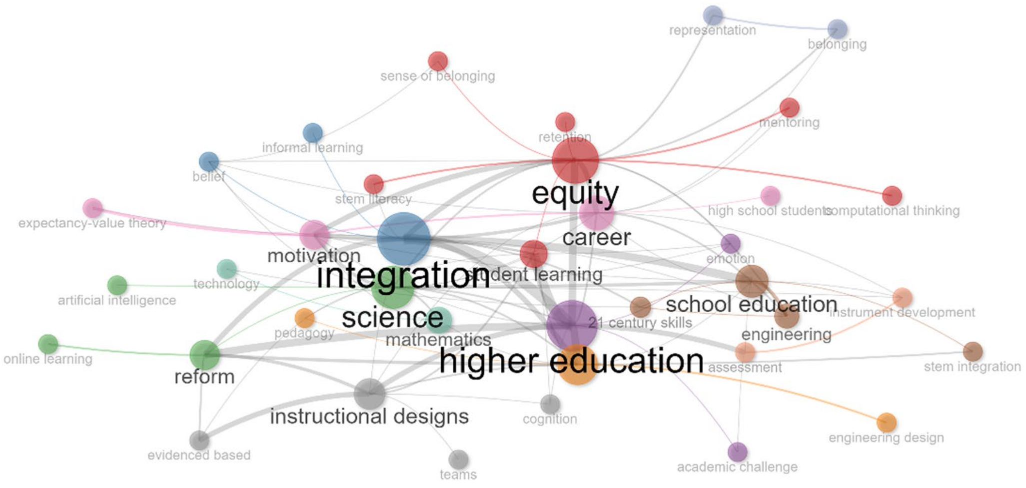

Fig. 4 Overall co-occurrence network of authors' keywords

further explore these connections, this study conducted a follow-up analysis for each cluster/theme to examine how sub-themes relate to one another within the network.

Motor themes

Integration, equity, and motivation are three major clusters/themes included in this group, indicating that these are both highly relevant and frequently studied themes. Figure 6 illustrates the network for the integration cluster/theme, which shows that STEM integration occurs in both K-12 schools and higher education, with science being one of the most commonly integrated components. This integration calls for reforms and innovative instructional designs, as well as professional development activities to support teacher learning.

Figure 7 shows the network for the equity cluster/theme, which stresses the importance of promoting STEM education among underrepresented groups, such as ethnic minorities and women. Strategies like career inspiration, mentorship, and fostering a sense of belonging are key to advancing equity in STEM education.

The last cluster/theme in this group is motivation, which shares some similarities with equity, as seen in Fig. 8. Career inspiration is a major motivator, especially within the African American community, according to the network. These three primary clusters, integration, equity, and motivation, are the most extensively researched areas in STEM education.

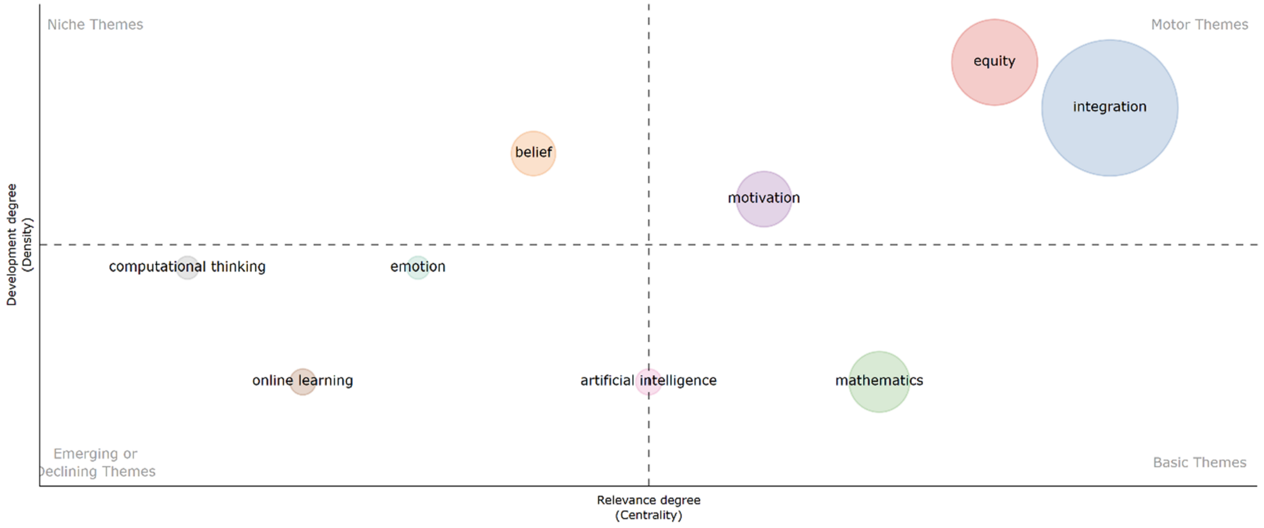

Fig. 5 A thematic map of authors' keywords

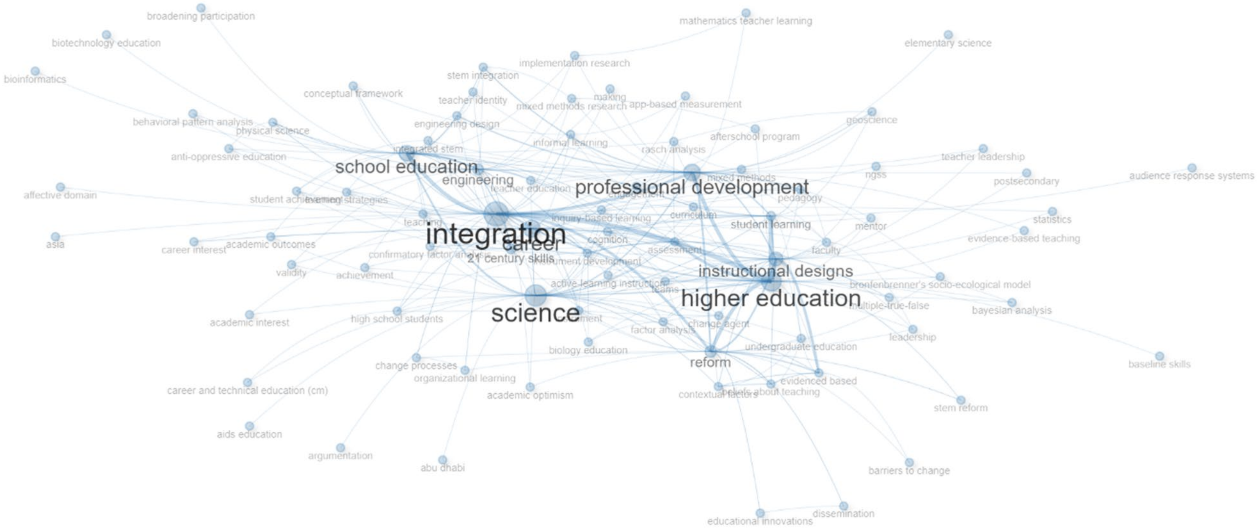

Fig. 6 The network of the theme of integration

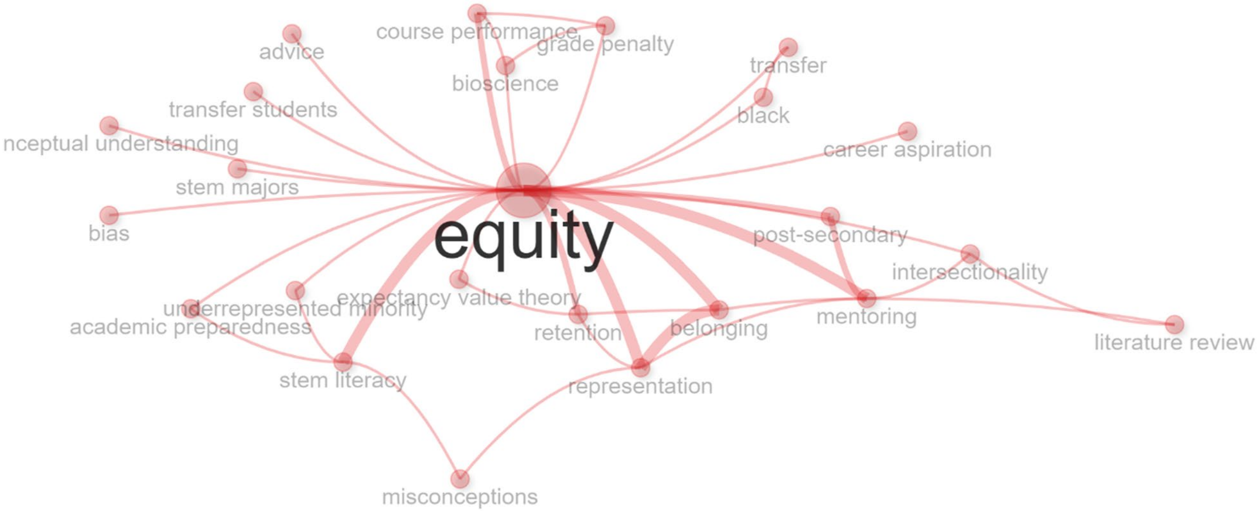

Fig. 7 The network of the theme of equity

Fig. 8 The network of the theme of motivation

Basic themes

One key cluster/theme identified in this group is mathematics. Despite its high relevance, it is less developed compared to other themes. This cluster/theme also encompasses technology and technology-enhanced learning (e.g., 3D technology) as shown in Fig. 9. Science and engineering education receive greater attention than mathematics and technology education as seen in Fig. 6. It is essential to increase research on mathematics

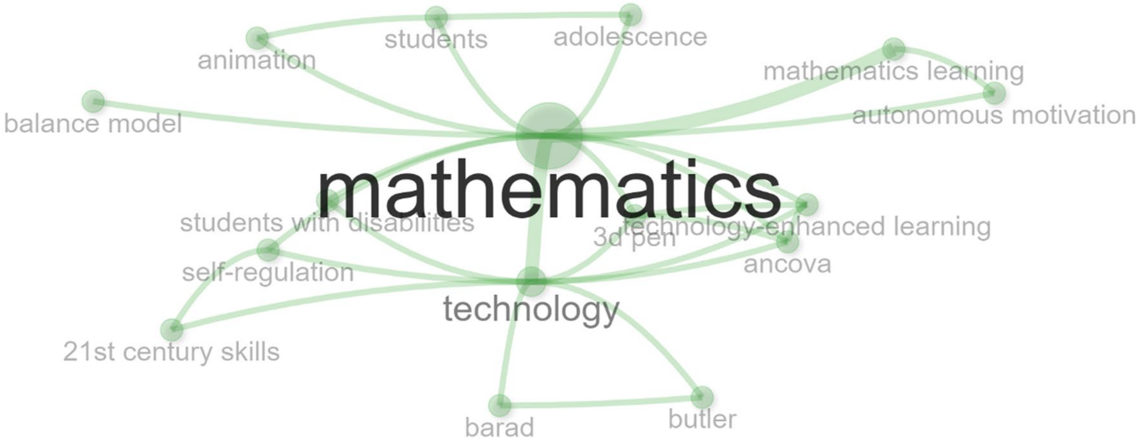

Fig. 9 The network of the theme of mathematics

and technology education within the STEM context. For example, exploring how technology can support mathematics learning. The network also indicates that there is a growing trend toward technology-enhanced learning in mathematics education.

Niche themes

A small cluster/theme identified in this group is belief, which shows a high degree of development but low relevance. Although belief is a well-studied topic, it is more strongly connected to attitude and career inspiration, influencing participation in communities of practices, makerspaces, and authentic learning, as shown in Fig. 10. However, this cluster/theme is not a primary area in STEM education research.

Emerging/declining themes

There are three direct clusters/themes: computational thinking, emotion, online learning, and one overlapping cluster/theme of artificial intelligence (AI). AI lies at the intersection of emerging/declining and basic themes. As most studies on AI in education have occurred after 2018, we suggest that this is an emerging area. The other three clusters/themes, aside from emotion, are tied to modern technologies. Emotion is becoming a growing focus in current research, particularly in complex learning environments. Hence, we suggest all four clusters/themes should be seen as emerging rather than declining.

Figure 11 presents the network for computational thinking. Research on computational thinking shows an emphasis on gender differences, curriculum development, and primary education. Encouraging computational thinking in students, especially in younger

Fig. 10 The network of the theme of belief

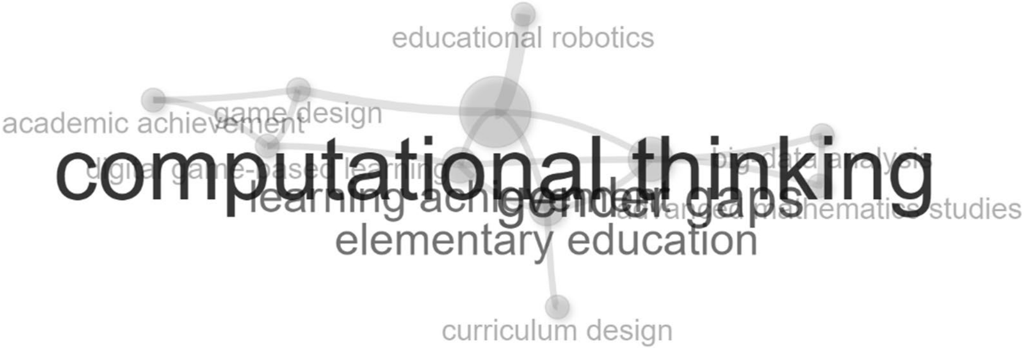

Fig. 11 The network of the theme of computational thinking

Fig. 12 The network of the theme of online learning

Fig. 13 The network of the theme of AI

children, requires a well-designed curriculum that is gender inclusive.

The cluster/theme of online learning is still relatively new to STEM education. The network, as illustrated in Fig. 12, indicates that this line of work focuses on research-based instructional strategies and student experiences.

Figure 13 illustrates the AI cluster/theme. The network reveals that its current research is still in its early stages, with a focus on student and teacher motivation. Some studies explore how AI can be integrated into education.

Fig. 14 The network of the theme of emotion

The final cluster/theme in this group is emotion as shown in Fig. 14. The network reveals that most studies attempt to understand the role of anxiety in STEM education.

Overall, we conclude that the integration of STEM disciplines and education equity are identified as key cohesive factors in the current review, given their high centrality and density in the thematic map. STEM integration tends to emphasize science and engineering more than mathematics and technology, while education equity is primarily concerned about underrepresented groups, such as women and Black individuals. The map also indicates a significant shift toward studying the influence of technology on mathematics and AI within STEM education. Additionally, the map highlights the importance of understanding the development of students' computational thinking and the design of online STEM instruction. However, psychological topics do not appear to have a well-defined position within STEM education research.

Historiographic mapping (Goal 3)

Historiographic mapping aims to analyze key papers within their historical context and interconnections by examining the citation network of a specific study topic and the linkages between papers (Aria & Cuccurullo, 2017). This analysis provides a summary of how various studies have contributed to the development of a topic over time, while also identifying key papers within the research topic. Figure 15 displays the four clusters identified in the historiographic mapping.

Cluster 1 (orange), the smallest cluster, focuses on STEM education reform (e.g., student-centered learning, integration) from a scale-up and sustainability perspective (Foote et al., 2014; Knaub et al., 2016). The studies in this cluster suggest that research should serve as evidence for and preparation toward STEM education reform. Cluster 2 (blue) is the largest one and primarily investigates how to address STEM education reform by identifying challenges (e.g., assessment, teacher beliefs, instructional designs) and proposing solutions (Lund & Stains, 2015; Shadle et al., 2017). Cluster 3 (green) mainly concentrates on gender differences. Two studies published by Rainey and her colleagues (Rainey et al., 2018, 2019) are the main drivers of this cluster. The final cluster (purple) is shaped by two review studies by Margot and Kettler (2019) and Li et al. (2020a), and it suggests emerging research trends in STEM education.

Overall, this historiographic mapping shows that two key foci were STEM education reform and educational inequity, aligning with the findings of the previous analysis, specifically the nine clusters/themes (see Fig. 5).

Summary and discussion: What have we learned from the *International Journal of STEM Education*?

This review uses bibliometric analysis to examine papers published in the *International Journal of STEM Education* between 2014 and 2023. The descriptive analysis reveals a growing trend in STEM education research, as reflected in the increasing number of publications. The review presents five major implications as follows:

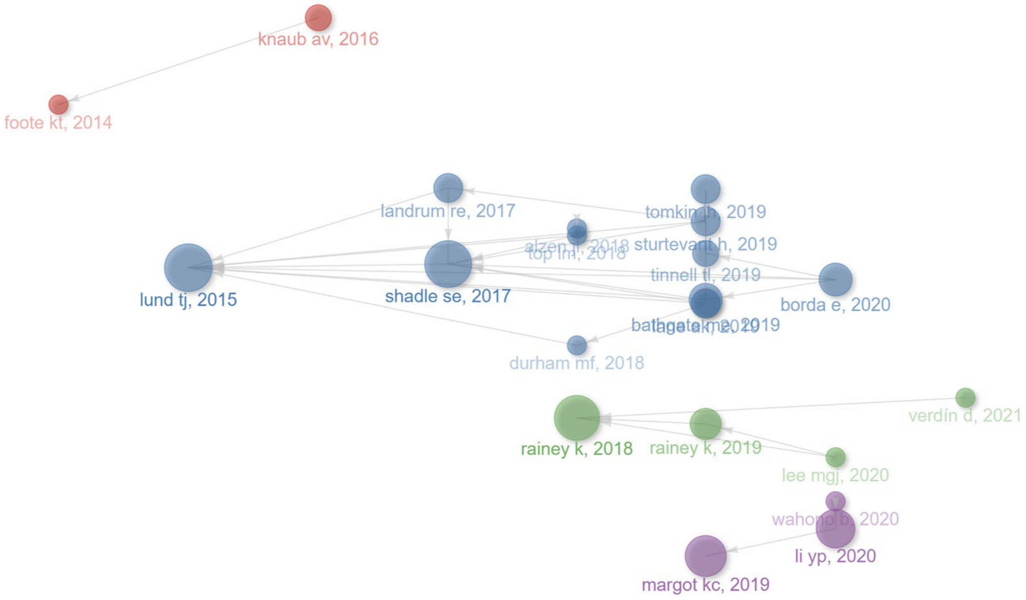

Fig. 15 The results of the historiographic mapping

STEM education representations

Among the four STEM disciplines, our analysis reveals a significant presence of science education researchers as prominent contributors to the field of STEM education, based on the volume of published papers. This finding aligns with one of the motor themes, integration (which includes science topics), and is reflected in the top 10 most-cited papers (e.g., Lund & Stains, 2015). Science education research plays a crucial role in driving STEM education, as seen in studies examining factors influencing female students' STEM motivation in science education colleges (Dökme et al., 2022), exploring the growth of STEM interest through informal scientific education programs (Habig & Gupta, 2021), and investigating STEM anxiety through science test performance (Rozgonjuk et al., 2024). These findings suggest that science learning is frequently studied for its direct impact on STEM education as a whole.

In STEM-integrated education research, our results indicate that mathematics and technology (e.g., using tools and machines to solve real-world problems) are underrepresented in comparison to science and engineering (e.g., the process of creating and testing structures and products). While these areas are researched, they remain less prominent. Recent mathematics education studies have utilized technology-related means to promote student performance, for example, data science (Ow-Yeong et al., 2023), robot-based games (Alfieri et al., 2015), and coding or computational thinking (Liu et al., 2024).

Integrated STEM education

Definitions and implementation of STEM integration remain unclear, ambiguous, and challenging (Margot & Kettler, 2019; Reinholz & Andrews, 2020). Our results show that integration occurs at both K-12 and higher education levels. Successful integration requires a comprehensive overhaul of STEM education, including curriculum and instructional design, with teachers playing a pivotal role in this transformation (Gale et al., 2020; McLure et al., 2022). Professional development should focus on enhancing teachers' beliefs, content knowledge, and pedagogical skills (Reinholz & Andrews, 2020; Shadle et al., 2017; Shernof et al., 2017).

Our results further reveal that computational thinking is an emerging research topic in integrated STEM education, especially in K-12 education (Chen et al., 2023; El-Hamamsy et al., 2023). This approach connects the four STEM disciplines, science, technology, engineering, and mathematics (Chen et al., 2023; Hurt et al., 2023), leading to better understanding and increased motivation and engagement. Teachers play a crucial role in integrating computational thinking into STEM education (Liu et al., 2024). Professional development activities in STEM education should explicitly address the teaching and application of computational thinking (Liu et al., 2024).

AI as an integral part of STEM education

AI education is increasingly recognized as a key component of STEM education (Casal-Otero et al., 2023). Our findings highlight the importance of ensuring that students understand AI-related ethical issues, address these challenges, and work to minimize their negative impact on STEM education (Nam & Bai, 2023; Usher & Barak, 2024). The results also suggest a need for more research on both student and teacher competencies in AI.

Using digital technology to support STEM learning and teaching

Utilizing technology to enhance STEM learning is gaining popularity. For example, using the metaverse virtual space has been shown to foster programming skills (Yang et al., 2024) and science and engineering practical skills (Chen & Huang, 2024). Online assessments, as well as adaptive and collaborative learning, have been found to effectively improve student performance, satisfaction, and engagements (Gamage et al., 2022). Therefore, integrating digital technology has become one of the most effective pedagogical strategies in STEM education.

Psychological constructs and equity

There is still a significant issue of educational equity in STEM education, particularly with respect to gender and ethnic identity. Our results indicate that underrepresented groups include women and Black individuals (Kricorian et al., 2020; Rainey et al., 2018). Improving the sense of belonging, reducing bias, and changing mindsets through mentoring, increasing representation, and inspiring career prospects can strengthen the STEM identity of these underrepresented groups (Blotnicky et al., 2018; Nkrumah & Scott, 2022).

In classroom teaching, our findings suggest that certain pedagogical approaches, such as engaging students in authentic research and providing strong instructor support, can motivate students from underrepresented group to pursue STEM (Habig & Gupta, 2021; Stolk et al., 2021). This is crucial for building a diverse and capable future STEM workforce.

Our results further reveal that psychological constructs (e.g., motivation, beliefs, emotions, interest, and identity) significantly impact STEM learning. The findings suggest that students' preferences and motivational beliefs are linked to their STEM career choices, both in high school (Rosenzweig & Chen, 2023) and colleges (Rosenzweig et al., 2024). Moreover, students' authentic learning experiences help develop a sense of belonging and foster positive STEM interests and identities (Habig & Gupta, 2021; Singer et al., 2020).

Teachers' STEM identities also play a crucial role in the success of STEM education (El Nagdi et al., 2018; Galanti & Holincheck, 2022), and these identities can be shaped through professional development activities (Jiang et al., 2021).

Overall, the results of our review suggest that the research areas of STEM education are still in their growth stages, with many unanswered questions remaining, such as "What is integrated STEM?" and "Why do we need integrated STEM?" (Wilson, 2021). Although this review is limited to papers published in the *International Journal of STEM Education* over its first decade (2014–2023), the findings align with trends revealed in other reviews that examine a broader range of journals (Li et al., 2020a, 2022). We encourage readers to reflect on these findings as a foundation for formulating future research agendas and driving the continued development of STEM education.

Limitations and conclusion

There are three limitations to this study: first, we rely on the Web of Science database, which is pertinent to STEM education studies; however, other databases could also provide valuable insights with different paper inclusion for analyses and citation measures. Second, our dataset covers only 10 years of publications, meaning our conclusions may be incomplete, particularly regarding intellectual structures that are still in their early stages. Third, this study is limited to bibliometric analysis, and we did not conduct an in-depth content analysis for a systematic literature review.

Despite these limitations, this study identifies and highlights key research areas and their structures, offering valuable guidance for future research in STEM education, particularly from the perspective of the *International Journal of STEM Education*.

Abbreviations

AI	Artificial intelligence
IF	Impact factor
JCR	Journal citation reports
TC	Total citations
TCP	Total citations per year
SSCI	Social sciences citation index
STEM	Science, technology, engineering, and mathematics

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Author contributions

YL initiated and organized this joint effort. TKC retrieved data from the Web of Science and conducted the data analyses. TKC and YL developed the manuscript draft. MD, JH, and MDK reviewed the drafts and contributed to the manuscript revisions. All authors read and approved the final manuscript.

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Availability of data and materials

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Declarations

Competing interests

The authors declare no competing interests.

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