International Journal of Modern Education
EISSN: 2637-0905
IJMOE
Volume 7 Issue 26 (September 2025) PP. 237-252
DOI: 10.35631/IJMOE.726016

INTERNATIONAL JOURNAL OF MODERN EDUCATION (IJMOE)
www.ijmoe.com

GLOBAL RESEARCH TRENDS ON SCIENTIFIC CURIOSITY IN STEM EDUCATION: A BIBLIOMETRIC AND VISUAL ANALYSIS

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Article Info:

Article history:
Received date: 30.06.2025
Revised date: 21.07.2025
Accepted date: 15.08.2025
Published date: 01.09.2025

To cite this document:

Hussain, W. N. H. W., Fadzil, H. M., & Shahali, E. H. M. (2025). Global Research Trends on Scientific Curiosity in Stem Education: A Bibliometric and Visual Analysis. *International Journal of Modern Education, 7* (26), 237-252.

DOI: 10.35631/IJMOE.726016

Abstract:

This study investigates global research trends on scientific curiosity within the context of STEM education through a comprehensive bibliometric and visual analysis. Scientific curiosity is increasingly recognized as a key driver of inquiry-based learning, problem-solving, and sustained engagement in the fields of Science, Technology, Engineering, and Mathematics (STEM). Despite its theoretical importance, a systematic examination of how scientific curiosity has been conceptualized and advanced within STEM education remains lacking. To address this gap, a bibliometric analysis was conducted on 2,062 documents retrieved from the Scopus database, covering publications from 2020 to 2025. Data were cleaned and standardized using OpenRefine and analyzed through Scopus analytical tools and VOSviewer to map publication trends, keyword co-occurrences, co-authorship networks, and international collaborations. The results indicate a steady increase in related publications, with the United States, China, and Australia emerging as leading contributors. Keyword analysis highlights central research themes, including student engagement, inquiry-based learning, educational technology, and STEM pedagogy. Co-authorship network mapping reveals a growing trend of international collaboration, particularly among institutions in North America, Europe, and Asia. Furthermore, the analysis reflects a shift in research focus driven by digital transformation and the COVID-19 pandemic, as evidenced by the frequent use of terms related to remote learning and artificial intelligence. In summary, this study delineates the evolving landscape of scientific curiosity research within STEM education and identifies emerging areas of focus. The findings provide a foundational reference for future research, educational policy formulation, and pedagogical innovation aimed at fostering curiosity-driven learning in diverse and technologically evolving STEM contexts.

Keywords:

Scientific Curiosity, Stem Education, Bibliometric Analysis, Inquiry-Based Learning, Educational Technology, International Collaboration, Visual Mapping

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Introduction

Scientific curiosity plays a pivotal role in Science, Technology, Engineering, and Mathematics (STEM) education, significantly influencing students' learning outcomes and engagement. Research indicates that science curiosity is a critical cognitive-developmental determinant that drives students' acquisition of knowledge and skills within scientific domains (Eren & Dökme, 2024; Wu & Wu, 2020). Factors such as gender, family income, and parental education can impact levels of science curiosity, with girls and students from middle-income families showing higher curiosity levels (Eren & Dökme, 2024; Singh & Manjaly, 2022). Additionally, creating home-like science learning environments with caring educators and rich materials can stimulate curiosity, especially for students who lack family involvement (Eren & Dökme, 2024; Weible & Zimmerman, 2016). This highlights the importance of tailored educational policies and environments to foster curiosity in diverse student populations.

Curiosity is often minimized in formal and informal science education due to a focus on right and wrong answers, which can negatively impact participation and engagement (Arnone et al., 2011; Berland et al., 2018; Lindholm, 2018). To counter this approaches such as Curiosity Practices help parents and children develop a sense of curiosity about natural phenomena (Berland et al., 2018; Russ & Berland, 2019). Curiosity-driven questioning and inquiry are essential for developing scientific thinking and motivation (Jirout, 2020; Papendieck & Clarke, 2024). Engaging students in inquiry-based learning and problem-solving activities can promote deeper understanding and critical thinking skills, as seen in programs like Discovery, which focuses on biomedical engineering and has shown positive outcomes in student engagement and performance (Callaghan et al., 2020; Ragab et al., 2024).

Implementing active learning strategies and interdisciplinary approaches can further enhance students' engagement and curiosity in STEM subjects (Joshi & Padhi, 2023). For example, Project-Based Learning (PjBL) in engineering courses has been shown to improve conceptual understanding, problem-solving proficiency, and critical thinking skills (Singh, 2024). Similarly, educational robotics and storytelling in physics education can foster creativity and curiosity among students (Arís & Orcos, 2019; Tuveri & Steri, 2025). These methods emphasize the importance of experiential learning and real-world applications, preparing students for future STEM careers and promoting a lifelong interest in scientific inquiry.

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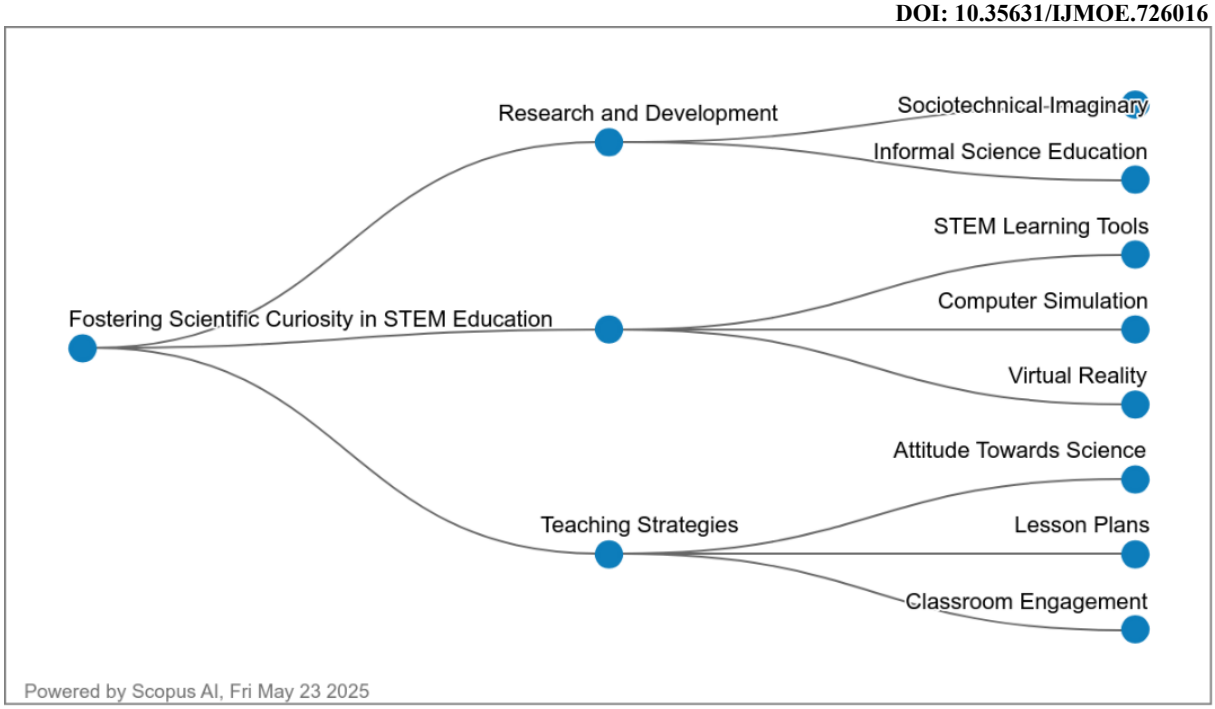

Figure 1: Overview Of Scientific Curiosity In STEM Education.

Research Question

RQ1: What are the research trends in scientific curiosity in STEM education according to the year of publication?
RQ2: What are the top 10 cited articles?
RQ3: What are the top 10 countries based on the number of publications?
RQ4: What are the most popular keywords related to the study?
RQ5: What is co-authorship by countries collaboration?

Methodology

Bibliometric analysis involves the systematic collection, organization, and examination of bibliographic information derived from scientific literature (Alves et al., 2021; Assyakur and Rosa, 2022; Verbeek et al., 2002). In addition to basic descriptive statistics such as identifying prominent journals, publication years, and leading authors (Wu and Wu, 2017), bibliometric methods also encompass advanced analytical procedures, including document co-citation analysis. Conducting an effective literature review requires a careful and repetitive process, which includes selecting appropriate search terms, retrieving relevant literature, and performing detailed content analysis. This structured approach facilitates the development of a comprehensive and dependable bibliography (Fahimnia et al., 2015). Accordingly, the study concentrated on publications with high citation impact, as these works often reflect influential theoretical contributions to the research area. To ensure the accuracy of data, Scopus was selected as the primary database for literature retrieval (Al-Khoury et al., 2022; di Stefano et al., 2010; Khiste and Paithankar, 2017). To maintain the quality of sources, only articles published in peer-reviewed academic journals were included. Meanwhile, books and lecture notes were intentionally excluded (Gu et al., 2019). The dataset comprised publications indexed in Elsevier's Scopus database, spanning the period from 2020 to 2025.

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Data Search Strategy

This study employed a systematic data search strategy to retrieve relevant literature for bibliometric analysis using the Scopus database. The search was designed to capture research at the intersection of scientific curiosity and STEM education. The final search string applied was: `TITLE-ABS-KEY ("curiosity" OR "scientific curiosity" OR "science curiosity" OR "curiosity-driven" OR "inquiry-based learning" OR "exploration" OR "investigation" OR "questioning" OR "student interest" OR "student engagement") AND TITLE-ABS-KEY ("STEM education" OR "science education" OR "technology education" OR "engineering education" OR "mathematics education") AND PUBYEAR > 2019 AND PUBYEAR < 2026 AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (SUBJAREA, "SOCI")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SRCTYPE, "j"))`. This query was constructed to retrieve only peer-reviewed journal articles published in English between 2020 and 2025, classified under the Social Sciences subject area. The inclusion of a broad range of curiosity-related keywords, such as "inquiry-based learning," "exploration," and "student engagement," ensured thematic alignment with the concept of scientific curiosity. The STEM education focus encompassed the domains of STEM education. The restriction to journal articles ensured academic rigor and the exclusion of less formal publication types. The time range was selected to reflect recent scholarly discourse, particularly in light of evolving educational practices and post-pandemic curriculum changes. The resulting dataset provided a focused and current foundation for bibliometric analysis. The execution of this query yielded a total of 2,062 documents. This dataset served as the foundation for the bibliometric and visual analysis conducted in the present study. The selection of the publication period from 2020 onwards was motivated by a focus on recent research developments and emerging trends in STEM education, particularly in relation to curiosity-driven pedagogy in contemporary contexts.

Table 1: The Search String

Scopus	TITLE-ABS-KEY ("curiosity" OR "scientific curiosity" OR "science curiosity" OR "curiosity-driven" OR "inquiry-based learning" OR "exploration" OR "investigation" OR "questioning" OR "student interest" OR "student engagement") AND TITLE-ABS-KEY ("STEM education" OR "science education" OR "technology education" OR "engineering education" OR "mathematics education") AND PUBYEAR > 2014 AND PUBYEAR < 2026 AND PUBYEAR > 2019 AND PUBYEAR < 2026 AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (SUBJAREA, "SOCI")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (SRCTYPE, "j")).

Table 2: The Selection Criterion is Searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2020 – 2025	< 2020
Subject	Journal (Article)	Conference, Book, Review
Publication Stage	Final	In Press

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Data Analysis

VOSviewer is a bibliometric visualization tool created by Nees Jan van Eck and Ludo Waltman at Leiden University, Netherlands (van Eck & Waltman, 2010, 2017). It is widely recognized for its capacity to support the visualization and interpretation of scientific literature. The software excels in constructing intuitive network visualizations, clustering thematically related elements, and producing density-based maps. Researchers frequently employ VOSviewer to explore co-authorship relations, co-citation patterns, and keyword co-occurrence, facilitating a nuanced understanding of scholarly landscapes. Its interactive features and regular updates allow for the dynamic handling of large bibliographic datasets. The software's ability to generate analytical metrics, offer customizable visual outputs, and integrate various bibliometric data sources enhances its value as a research tool.

A notable strength of VOSviewer lies in its ability to convert complex bibliometric data into easily interpretable visual representations. Prioritizing network-based visual analytics, it effectively clusters related data points identifies keyword associations and visualizes density patterns. The interface is designed for ease of use, accommodating both novice and experienced users in the exploration of academic domains. VOSviewer continues to evolve, maintaining its relevance in bibliometric research by supporting metric computation and flexible visual configurations. Its broad applicability to diverse data types, including citation and authorship networks, affirms its role as a critical instrument for in-depth scholarly analysis.

Bibliographic data, including publication year, title, authorship, journal name, citation count, and keywords, were exported from the Scopus database in PlainText format, covering publications from 2020 to 2025. This data was processed using VOSviewer version 1.6.20. through its mapping and clustering capabilities, VOSviewer enabled the creation of visual maps that represent the underlying bibliometric structures. Unlike the traditional Multidimensional Scaling (MDS) method, VOSviewer positions items within a low-dimensional space in a manner that reflects their degree of relatedness (van Eck & Waltman, 2010). Meanwhile, both approaches aim to visualize item similarity, and MDS typically utilizes similarity measures such as the cosine or Jaccard indices (Appio et al., 2014). In contrast, VOSviewer adopts a more appropriate method for normalizing co-occurrence frequencies, known as Association Strength (AS_{ij}), which is calculated using the following formula (van Eck and Waltman, 2007):

$$AS_{ij} = \frac{C_{ij}}{w_i w_j}.$$

This metric reflects the ratio between the actual co-occurrence count of items *i* and *j* and the expected frequency of their co-occurrence under the assumption of statistical independence (van Eck & Waltman, 2007).

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Findings

What Are The Research Trends In Scientific Curiosity In STEM Education According To The Year Of Publication?

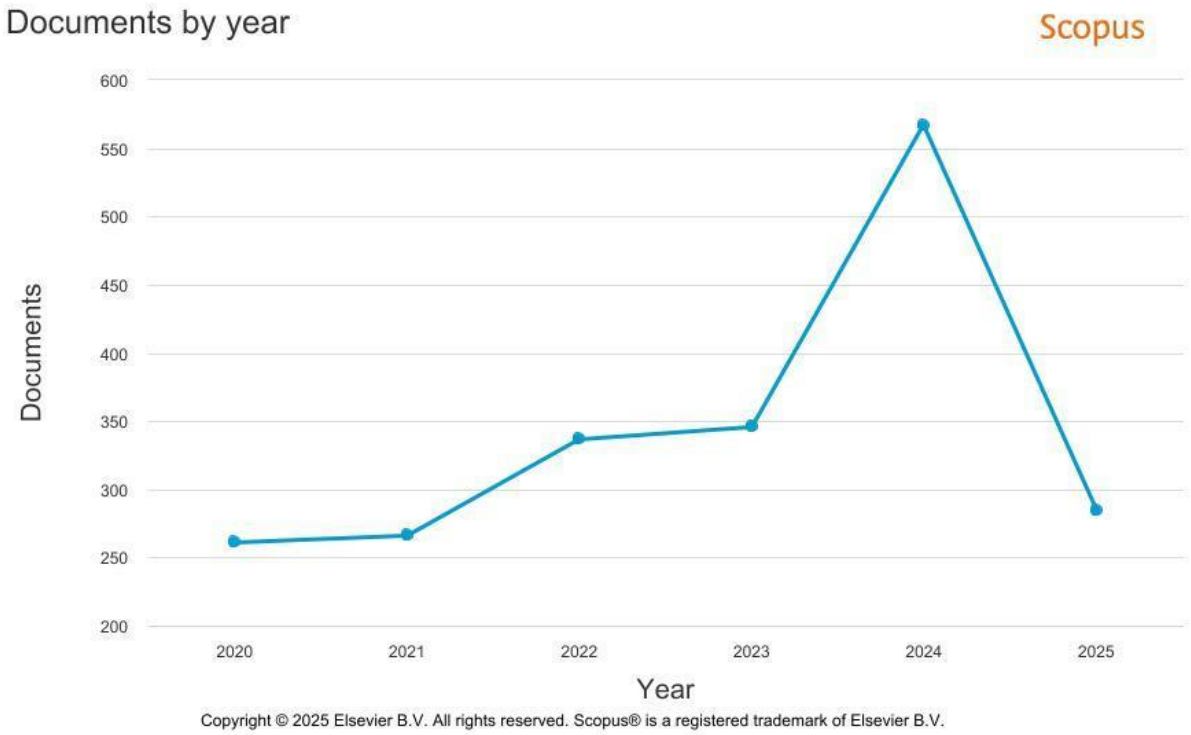

Figure 2: Trend of Research in Scientific Curiosity in STEM Education by Years

Table 3: Total Publications Based on the Year

Year	Total publication	Percentage %
2025	285	13.82
2024	567	27.50
2023	346	16.78
2022	337	16.34
2021	266	12.90
2020	261	12.66

The temporal distribution of publications on scientific curiosity in STEM education from 2020 to 2025 reveals a steadily increasing scholarly interest, particularly in the most recent years. As observed in the dataset, the number of publications rose significantly from 261 in 2020 to 567 in 2024, representing the highest annual output (27.50%). This upward trend suggests a growing global emphasis on integrating curiosity-driven pedagogies within STEM education, possibly spurred by the heightened demand for innovative teaching approaches in response to the COVID-19 pandemic's impact on educational systems.

Between 2020 and 2022, the annual publication count increased moderately, rising from 261 in 2020 to 337 in 2022, indicating a foundational phase of scholarly engagement with the topic. These years account for approximately 41.90% of the total publications, reflecting steady and incremental growth. The consistent output during this period may be attributed to ongoing

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debates surrounding 21st-century skills development, which increasingly emphasize scientific curiosity as a critical component of inquiry-based STEM learning. It also mirrors the global push toward digital transformation in education, which has fostered research into student engagement and motivation, particularly in technologically enriched learning environments.

The years 2023 to 2025 maintain this momentum, accounting for over 47% of the total publications, with 2024 alone contributing more than one-quarter of the total output. The slight drop in 2025 (13.82%) compared to 2024 may be due to incomplete data availability at the time of analysis, as future publications are still being indexed. Overall, the data strongly indicate that scientific curiosity within STEM education has emerged as a rapidly expanding field of research. This sustained increase in scholarly output underscores its growing significance in educational policy, curriculum development, and instructional design, with researchers worldwide increasingly recognizing the importance of fostering curiosity to support deeper, lifelong learning in STEM disciplines.

What Are The Top 10 Cited Articles?

Table 4: The Top 10 Cited Articles

Authors	Title	Year	Source Title	Cited by
Wardat Y.; Tashtoush M.A.; AlAli R.; Jarrah A.M.	ChatGPT: A revolutionary tool for teaching and learning mathematics (Wardat et al., 2023)	2023	Eurasia Journal of Mathematics, Science and Technology Education	203
Rahiem M.D.H.	The emergency remote learning experience of university students in Indonesia amidst the COVID-19 crisis (Rahiem, 2020)	2020	International Journal of Learning, Teaching, and Educational Research	159
Mamun M.A.A.; Lawrie G.; Wright T.	Instructional design of scaffolded online learning modules for self-directed and inquiry-based learning environments (Mamun et al., 2020)	2020	Computers and Education	149
Demitriadou E.; Stavroulia K.-E.; Lanitis A.	Comparative evaluation of virtual and augmented reality for teaching mathematics in primary education (Demitriadou et al., 2020)	2020	Education and Information Technologies	133
Skilling K.; Stylianides G.J.	Using vignettes in educational research: a framework for vignette construction (Skilling & Stylianides, 2020)	2020	International Journal of Research and Methods in Education	121

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Bergdahl N.; Nouri J.; Fors U.; Knutsson O.	Engagement, disengagement, and performance when learning with technologies in upper secondary school (Bergdahl et al., 2020)	2020	Computers and Education	120
Makransky G.; Petersen G.B.; Klingenberg S.	Can an immersive virtual reality simulation increase students' interest and career aspirations in science? (Makransky et al., 2020)	2020	British Journal of Educational Technology	119
Zhai C.; Wibowo S.	A systematic review on artificial intelligence dialogue systems for enhancing English as a foreign language students' interactional competence in the university (Zhai & Wibowo, 2023)	2023	Computers and Education: Artificial Intelligence	114
Code J.; Ralph R.; Forde K.	Pandemic designs for the future: perspectives of technology education teachers during COVID-19 (Code et al., 2020)	2020	Information and Learning Science	108
Godwin A.; Kirn A.	Identity-based motivation: Connections between first-year students' engineering role identities and future-time perspectives (Godwin & Kirn, 2020)	2020	Journal of Engineering Education	103

The analysis of the top 10 most cited publications in the field of scientific curiosity and STEM education highlights key thematic and methodological trends that have attracted significant scholarly attention. Leading the list is the 2023 article by Wardat et al., titled "ChatGPT: A revolutionary tool for teaching and learning mathematics," which has already amassed 203 citations. This reflects the growing interest in integrating artificial intelligence into STEM education, particularly in the context of mathematics instruction. The prominence of AI-based tools, such as ChatGPT, signals a shift toward technology-enhanced learning environments where curiosity and inquiry are fostered through digital platforms.

A notable pattern among the highly cited works is the clustering of impactful publications in 2020, a year marked by the onset of the COVID-19 pandemic. Articles by Rahiem (159 citations), Mamun et al. (149), and Demitriadou et al. (133) delve into topics such as emergency remote learning, scaffolded instructional design, and immersive virtual and augmented reality.

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These studies reflect an urgent scholarly response to the disruptions in traditional education, prompting the exploration of innovative methods to sustain student curiosity and engagement in STEM disciplines during times of crisis. The repeated citation of these works suggests that the global educational community actively sought and built upon empirical insights into how students adapt to rapidly changing learning environments.

Furthermore, the scope of these top-cited articles encompasses both theoretical frameworks and practical applications, with a primary focus on enhancing learner motivation and cognitive engagement. For instance, Makransky et al.'s study on the influence of virtual reality on students' science career aspirations (119 citations) and Godwin & Kirn's investigation into identity-based motivation in engineering education (103 citations) illustrate the importance of affective and identity-related dimensions in STEM learning. The inclusion of diverse methodologies, from systematic reviews to empirical case studies, indicates a multidimensional approach to understanding how curiosity is cultivated and sustained in technologically mediated education. Collectively, these top-cited works highlight the importance of curiosity-driven, technology-supported, and learner-centered pedagogies in advancing STEM education research.

What Are The Top 10 Countries Based On Number Of Publications?

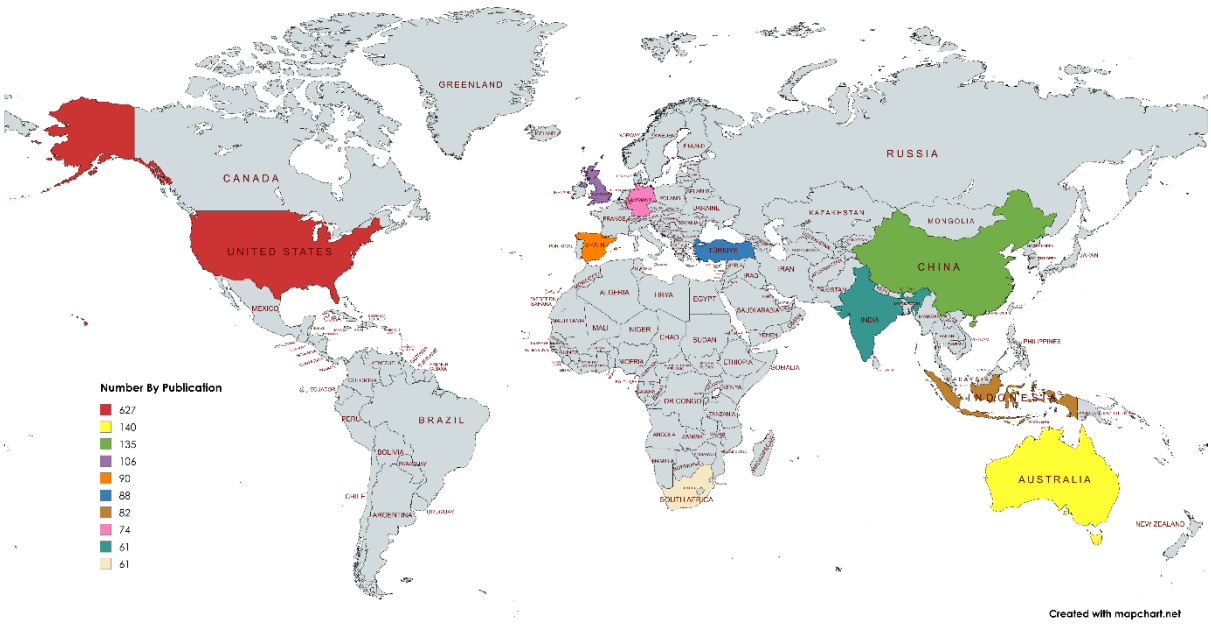

Figure 3: Top 10 Countries Based on the Number of Publications

The bibliometric data reveal that the United States leads by a substantial margin in the number of publications related to scientific curiosity in STEM education, contributing 627 documents. This dominant output reflects the country's longstanding investment in STEM initiatives, educational research infrastructure, and funding mechanisms aimed at fostering inquiry-based learning and student engagement. The high volume of scholarly work also indicates that U.S. researchers and institutions are deeply involved in exploring innovative pedagogies, including curiosity-driven learning, as part of national priorities to strengthen STEM competencies.

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Following the United States, countries such as Australia (140), China (135), and the United Kingdom (106) show strong scholarly participation, albeit at significantly lower levels. These nations are known for their progressive education policies, digital learning integration, and emphasis on developing 21st-century skills. Australia's notable presence may be attributed to its active research on inquiry-based learning and early STEM intervention programs. Similarly, China's rising contribution aligns with its strategic educational reforms and heavy investment in science and technology education. The United Kingdom's output reflects its research culture, which emphasizes student-centered approaches and STEM equity.

Mid-tier contributors such as Spain, Turkey, Indonesia, Germany, India, and South Africa reflect a growing global interest in the topic. These countries, each with 60–90 publications, represent diverse educational contexts and suggest an expanding discourse around STEM pedagogy beyond traditional Western centers of scholarship. For instance, Indonesia's active contribution highlights a regional focus on improving STEM engagement amidst digital transformation. At the same time, South Africa and India underscore the importance of curiosity-driven STEM education in developing contexts. The diversity of countries in the top 10 list indicates that scientific curiosity in STEM education is a globally relevant research area, shaped by both local educational needs and global pedagogical trends.

What Are The Most Popular Keywords Related To The Study?

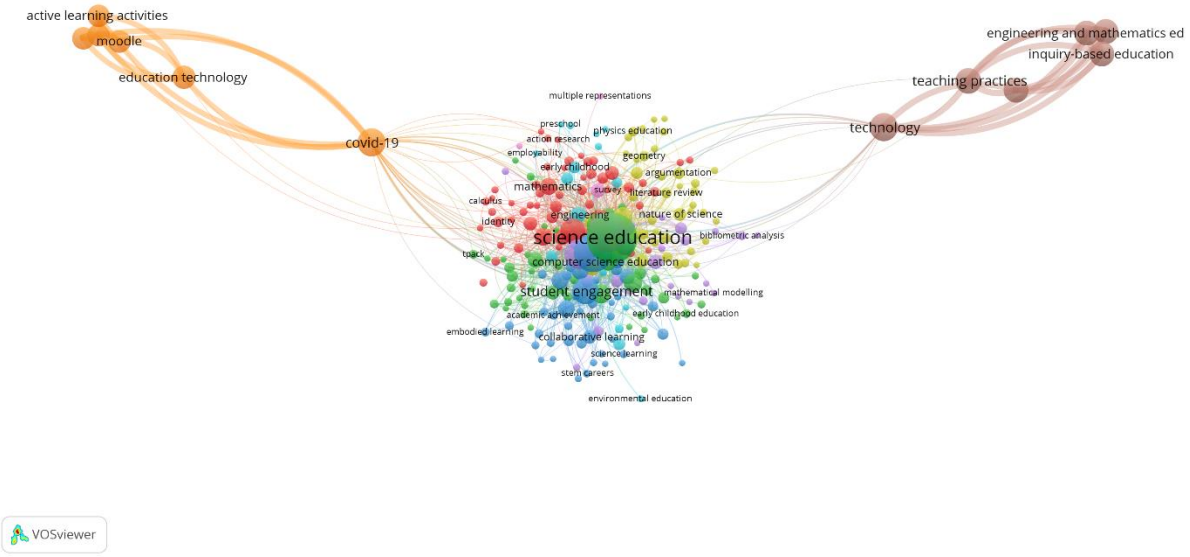

Figure 4: Network Visualization Map of Keywords' Co-Occurrence

Table 5: Top Keywords by Occurrence and Total Link Strength Related to this Study

No	Keyword	Occurrences	Total link strength
1	Science education	259	384
2	Technology	78	343
3	Teaching practices	65	314
4	Covid-19	79	312
5	Sciences	63	311

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6	Engineering and mathematics education	61	305
7	Formative-assessment	61	305
8	Inquiry-based education	62	305
9	Education technology	56	264
10	Moodle	52	257

Based on the VOSviewer keyword co-occurrence data, the most frequently occurring and influential keywords center around key themes in contemporary STEM education. The term "science education" stands out with 259 occurrences and a total link strength of 384, indicating its centrality in the field and frequent co-occurrence with a wide range of other keywords. Closely following are "engineering education" (88 occurrences) and "technology" (78 occurrences), highlighting the core domains within STEM that are most studied. Keywords such as "student engagement" (71), "inquiry-based learning" (74), and "education technology" (56) further emphasize the pedagogical focus of current research, particularly as it relates to curiosity-driven and student-centered learning approaches. The prominence of "formative assessment" (61) and "teaching practices" (65) also suggests a strong interest in evaluating and refining instructional strategies within STEM contexts.

Another emerging theme involves the integration of digital technologies and innovation. Keywords like "chatGPT" (22 occurrences, 48 link strength), "virtual reality" (23, 42), "game-based learning" (19, 34), and "artificial intelligence" (38, 69) reflect a growing research interest in the application of advanced technologies to support and enhance STEM learning environments. Notably, "Moodle" (52, 257) and "remote teaching and learning" (51, 255) show high link strength, indicating strong interconnectivity with other keywords, likely influenced by shifts in educational practice during the COVID-19 pandemic. This is further supported by "COVID-19" (79, 312), which ranks highly in frequency and demonstrates substantial thematic connectivity, revealing its pervasive impact on STEM education research.

Keywords related to student outcomes and motivation such as "academic performance" (10, 19), "academic achievement" (9, 27), "creativity" (16, 31), "critical thinking" (17, 25), and "self-efficacy" (25, 44) underscore the cognitive and affective aspects of STEM learning. The appearance of "professional development" (35, 68) and "teacher education" (32, 58) points to a parallel interest in teacher capacity building, aligning to foster curiosity and deeper learning in classrooms. Collectively, these patterns reveal that the field is rooted in disciplinary content and highly responsive to technological advances, pedagogical reform, and broader societal disruptions, offering a multidimensional view of curiosity in STEM education.

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What Is Co-Authorship By Countries Collaboration?

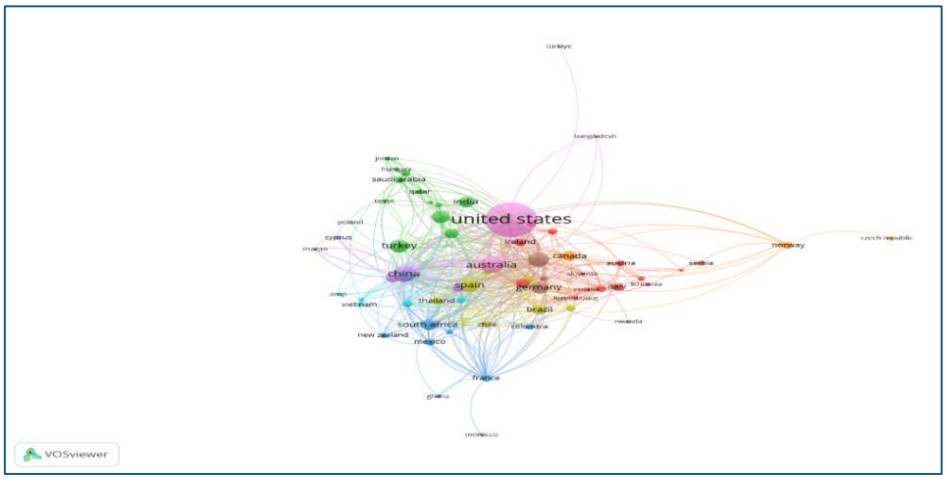

Figure 5: Network Visualization Map of Co-Authorship by Countries' Collaboration

The co-authorship data reveals that the United States is the most prolific and influential country in the field of curiosity-related STEM education research, with 627 documents, 4,678 citations, and the highest total link strength (163). This indicates not only a high research output but also strong collaborative ties with a wide range of international partners. Other highly productive countries include Australia (139 documents), China (134), and the United Kingdom (105). Despite producing fewer documents than the United States, these countries demonstrate significant collaboration and citation counts, suggesting they contribute substantively to global knowledge exchange. Notably, China surpasses Australia in link strength (112 vs. 102), underscoring its growing prominence in international research networks.

A second tier of active contributors includes countries such as Germany (73 documents, 682 citations, link strength 69), Spain (89, 509, 61), and South Africa (60, 266, 61). These nations are productive and well-integrated into international research networks, as evidenced by their high total link strengths. Hong Kong (49, 495, 57) and France (22, 134, 53) also display notable citation impact relative to their document output, suggesting that their research is both visible and influential. Countries such as Singapore, Sweden, and Taiwan also exhibit high link strengths in proportion to their document counts, indicating strong global collaborations.

In contrast, several emerging or regionally active countries, such as Indonesia (82 documents, 451 citations, link strength 28) and Malaysia (51, 396, 35), are making measurable contributions. However, their integration into the broader international network is still in development. Similarly, India (61 documents) and Turkey (87) demonstrate substantial research activity but relatively lower link strength (10 and 40, respectively), suggesting that much of their output may be domestically oriented or involve fewer international collaborations. Some smaller or less connected nations, such as Bangladesh, Peru, and Rwanda, show minimal link strength, highlighting potential opportunities for greater involvement in global research partnerships. Overall, the data reflect a dynamic landscape where traditional research leaders coexist with rapidly emerging contributors across both the Global North and South.

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Conclusion

This study aimed to examine global research trends on scientific curiosity within the context of STEM education through a bibliometric and visual analysis. The primary objective was to analyze the volume, growth, and thematic focus of scholarly output between 2020 and 2025, utilizing bibliometric tools to identify key patterns in publication trends, influential countries, keyword prominence, and collaborative networks. Through this investigation, the study addressed research questions concerning publication trends, top-cited articles, prolific countries, common keywords, and patterns of international co-authorship.

The findings revealed a continuous rise in publications from 2020 to 2024, with a particularly high output recorded in 2024. The United States emerged as the most productive and influential contributor, followed by China, Australia, and the United Kingdom. Keyword analysis showed that science education, student engagement, inquiry-based learning, and education technology were among the most frequently occurring and strongly linked concepts. Co-authorship networks highlighted strong international collaborations, particularly among institutions in North America, Europe, and parts of Asia, while several emerging countries demonstrated growing participation in the global research landscape. The integration of digital tools and artificial intelligence, as well as responses to pandemic-driven educational shifts, also featured prominently in recent publications.

The study contributes to the understanding of how scientific curiosity is addressed in STEM education literature and highlights the evolving priorities of the field. The results provide a foundation for shaping future inquiry, particularly in enhancing teaching strategies, integrating technology, and designing inclusive curricula. Limitations include the restriction to one database and a focus on journal articles, which may exclude relevant literature in other formats. Future studies could expand the scope by incorporating multiple databases, conducting longitudinal citation analyses, and employing more in-depth thematic categorization. Overall, the study demonstrates the value of bibliometric analysis in mapping scholarly landscapes and guiding future research in educational innovation and inquiry-based learning within STEM education.

Acknowledgment

The author wishes to express sincere appreciation to the academic mentors and scholars whose foundational work has significantly informed the exploration of scientific curiosity within STEM education. Deep gratitude is also extended to the 4th International Conference on Social Science, Education, and Business (ICOSEB 2025) for providing a valuable platform to present and disseminate the findings of this bibliometric and visual analysis to the wider academic and professional community.

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