JPII 14 (4) (2025) 743-754

Jurnal Pendidikan IPA Indonesia

https://journal.unnes.ac.id/journals/jpii

NON-STEM STUDENTS IN UNDERGRADUATE SCIENCE: A GLOBAL BIBLIOMETRIC REVIEW TOWARD SUSTAINABLE DEVELOPMENT GOAL 4 (2017–2025)

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DOI: 10.15294/jpii.v14i4.32211

Accepted: August 12th, 2025. Approved: December 22nd, 2025. Published: December 22nd, 2025

ABSTRACT

This bibliometric study analyzes 31 Scopus-indexed publications on non-STEM students in undergraduate science programs from 2017 to 2025, covering 23 sources and reporting an annual growth rate of 9.06% in research output. Using Biblioshiny and VOSviewer, the study examines publication trends, citation performance, collaboration structures, and thematic patterns. The earliest article in 2017 has a mean citation count of 27.44 per year, and the overall collaboration index indicates that multi-authored papers predominate, reflecting moderate to high co-authorship intensity in this niche field. Results show that the United States leads in publication volume and citation impact, followed by Hong Kong, Germany, Brazil, and China, while most other countries contribute only 1 or 2 articles. A small group of authors, institutions, and journals accounts for a large share of documents and citations, indicating a concentrated authorship and source structure. Keyword and thematic analyses reveal that research is primarily organized around course-level themes such as performance, engagement, and teaching approaches, with equity-, gender-, and policy-related topics emerging only in recent years as smaller, low-density clusters. These findings provide a baseline for understanding how research on non-STEM learners in science programs is distributed across authors, outlets, countries, and themes, and where further empirical work is needed to broaden and deepen this research area.

Keywords: bibliometric review; non-STEM students; undergraduate science programs; SDG 4

INTRODUCTION

Science education literature increasingly recognizes that non-STEM undergraduates encounter distinct difficulties in mastering scientific concepts, demonstrating lower confidence in science, weaker reasoning skills, and limited transfer of knowledge to daily decision-making compared to STEM peers (Larkin, 2015; Selco & Chan, 2020; Brooks et al., 2020; Gin et al., 2022; Mangubat, 2023; Khan et al., 2023). However, research involving this population commonly treats non-STEM learners as comparison groups rather than as the primary focus, resulting in fragmented knowledge about their learning trajectories and support needs (Thamer, 2022; Maphosa et al., 2022; Chinn et al., 2023; Mulyani et al., 2023; Suhirman & Prayogi, 2023; Solihah et al., 2024). As non-STEM enrollment in science courses continues to expand, the lack of a consolidated understanding of their learning challenges is increasingly concerning (Callier, 2014; Wladis et al., 2015; Lubis et al., 2021; Donley, 2024; Lucas & Vandergon, 2024; Bulasito, 2025; Chasen et al., 2025). There is an urgent need to synthesize available evidence before this research gap wi-

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dens further. This mismatch between expanding non-STEM participation in science courses and the absence of a coherent evidence base provides a strong rationale for a bibliometric review centered on this cohort (Impey et al., 2012; Taylor, 2015; Goodwin, 2022; Zhan et al., 2022; Shukla et al., 2023; Vijayamalar et al., 2024; Khalemsky et al., 2025; Faiz & Yusoff, 2025).

Commitments under SDG 4 and UNESCO's education agenda emphasize inclusive and equitable quality education, highlighting disparities linked to gender, socio-economic background, and disability in tertiary science learning environments (Hossain et al., 2023; Mangubat & Picardal, 2023; Bersoto et al., 2025; Cook-Chennault, 2025; Mangubat, 2025). Although women now constitute the majority of higher-education graduates globally, they remain underrepresented in STEM fields and research roles, a trend already documented in UNESCO's 2017 baseline reports and still evident in recent global findings (Honra, 2024; Lucas & Vandergon, 2024; Donley, 2024; Ahmad et al., 2024; Kertati et al., 2024). Socio-economically disadvantaged students also continue to score below science proficiency benchmarks (Ahmed et al., 2020; Bene et al., 2021; Comarú et al., 2021; Ma & Hui, 2023; Badmus et al., 2024; Goodwin & McKendree, 2024). These persistent inequities signal an urgent need to revisit existing frameworks using contemporary evidence from 2017–2025 and to position non-STEM learners more prominently in scientific literacy discourse. Without timely action, the achievement gap may continue to widen, leaving this population underserved in science education.

Existing bibliometric reviews have explored STEM education trends, technology integration, and 21st-century competencies, yet few specifically examine non-STEM undergraduates in science programs (Cotner, 2017; Martin-Raugh et al., 2022; Kundu et al., 2022; Beheshtian et al., 2023; Kondrashev et al., 2024; Sultanova & Shora, 2024). Current research is concentrated in high-income countries, with limited cross-country comparisons and minimal attention to gender and equity patterns among this learner group (Vega Montiel, 2018; Barboza, 2022; Dogan, 2023; Vaishya et al., 2024; Bezci & Sungur, 2025). These gaps demonstrate the urgency for a dedicated bibliometric mapping that highlights patterns, disparities, and areas where further empirical work is critically needed. Without such synthesis, non-STEM students risk being continually overlooked in policy, curriculum, and instructional reforms.

To address these gaps, this study conducts a bibliometric analysis of research on non-STEM undergraduates in science education from 2017 to 2025. The objectives are to: (1) generate a bibliometric map positioning non-STEM learners as the primary subject of inquiry, (2) examine publication volume, citation performance, and collaboration networks across countries and institutions, and (3) analyze the presence of equity, gender, and inclusive pedagogy themes in the conceptual structure of the field. The findings are expected to provide a comprehensive evidence base to support curriculum design, instructional innovation, and policy decisions aligned with SDG 4, thereby advancing science education curricula among non-STEM students. This work is timely and necessary to guide future research trajectories and ensure that non-STEM learners are not left behind in efforts to improve the quality and accessibility of science education.

METHODS

A bibliometric analysis was conducted using publications indexed in Scopus as of June 2025. Scopus was selected for its extensive interdisciplinary coverage of peer-reviewed research in science education. The search query was refined to avoid overly restrictive results and to capture articles using alternative terminology for non-STEM populations. The final query was:

TITLE-ABS-KEY ((“non-STEM” OR “non-science major*” OR “nonscience major*” OR “liberal arts student*” OR “general education student*” OR “non-STEM undergraduate*”)

AND (“science education” OR “science learning” OR “biology/chemistry/physics course*” OR “undergraduate science program*”)

AND (“performance” OR “learning outcomes” OR “achievement” OR “attitude” OR “engagement” OR “challenges” OR “opportunities”)) AND PUBYEAR > 2017 AND PUBYEAR < 2025.

The search initially identified 53 documents. After duplicate removal and automated filtering, 47 records were selected for screening. Title-abstract relevance assessment excluded non-empirical works and studies that did not involve non-STEM learners in science contexts. The full-text eligibility review resulted in 31 articles being retained for final analysis.

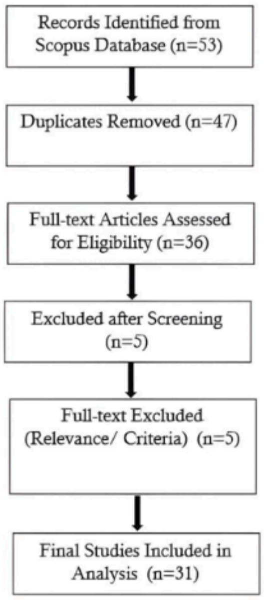

Figure 1. PRISMA Diagram of the Bibliometric Analysis

In this study, a bibliometric analysis was configured in Biblioshiny, using a minimum keyword occurrence of 3, the full-counting method, and association-strength normalization for co-word and co-authorship mapping. For VOSviewer, visual network construction used similar parameters: a minimum co-occurrence threshold of 3 keywords/authors, full counting, and association strength as the default normalization to generate keyword co-occurrence, bibliographic coupling, and co-citation networks.

Table 1. Analysis Parameter Table of the Bibliometric Analysis using Biblioshiny and VOSviewer

Software/ Tool	Parameter	Setting Used
Biblioshiny (Bibliometrix R)	Minimum keyword occurrence	≥ 3
	Counting method	Full counting
	Normalization method	Association Strength
	Minimum documents per author	≥ 2
	Minimum citations per document	≥ 5
	Type of analysis performed.	Annual production, author productivity, source impact, thematic mapping, co-word network, collaboration network
VOSviewer	Minimum keyword co-occurrence	≥ 3
	Counting method	Full counting
	Normalization method	Association Strength
	Minimum citations for co-citation analysis	$\geq$ 10 citations/reference
	Layout used	LinLog/Fruchterman-Reingold
	Visualization generated	Co-authorship, keyword co-occurrence, bibliographic coupling, co-citation clusters, overlay & density visualization

The analysis parameter table summarizes the specific settings and thresholds applied during bibliometric processing with Biblioshiny and VOSviewer to ensure the consistency and reliability of the results. A minimum keyword occurrence of 3 was set for both tools to include only frequently recurring terms, while full counting was used to give equal weight to each publication in which a keyword or author appears. Association strength served as the normalization method, allowing for more precise visualization of relationships among keywords, authors, and documents based on their co-occurrence intensity. In Biblioshiny, additional thresholds, such as at least two documents per author and five citations per article, facilitated author productivity and citation impact analysis. Meanwhile, VOSviewer applied a minimum threshold of three keyword links and ten citations for co-citation analysis, and used LinLog/Fruchterman-Reingold layout for cluster mapping. These parameters collectively enhanced the validity of the bibliometric networks and thematic structures generated in the study.

RESULTS AND DISCUSSION

The data hereunder consist of the general information of the data set, publication growth, and average citation, authors' production over time, institutional productivity, country scientific production, most cited countries, thematic map visualization, and keyword co-occurrence network in non-STEM science education research from 2017 to 2025, presented in tables and figures.

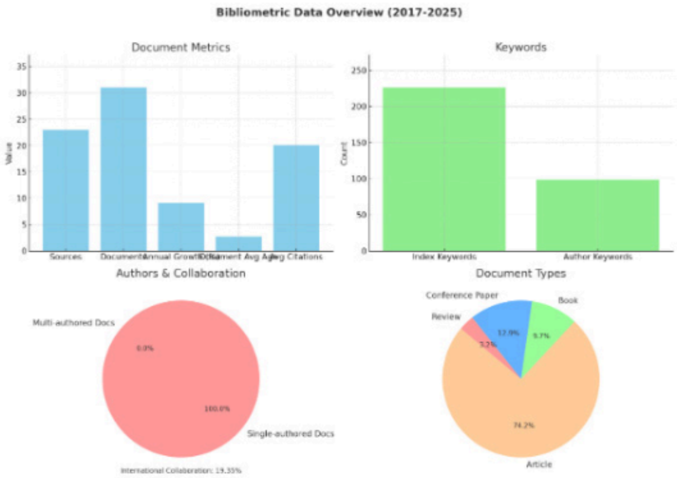

Figure 2. General Information about the Bibliometric Dataset

The dataset comprises 31 documents published between 2017 and 2025, with an annual growth rate of 9.06% and a moderate collaboration index of 20.06 per document. Output increases from 1–3 articles per year in 2017–2019 to 6–9 articles in 2022–2024, while mean citations per article are highest for early publications and lower for 2024–2025 because of citation recency. This pattern indicates a transition from sporadic to sustained production within a still-small research niche.

Table 2. Publication Growth and Average Citation in non-STEM Research Articles

Year	Articles	MeanTCperArt	N	MeanTCperYear	Citable Years
2017	1	247.00	1	27.44	9
2018	1	36.00	1	4.50	8
2019	3	41.00	3	5.86	7
2020	2	2.00	2	0.33	6
2021	2	55.00	2	11.00	5
2022	6	7.00	6	1.75	4
2023	6	4.83	6	1.61	3
2024	9	3.67	9	1.83	2
2025	2	0.00	2	0.00	1

Publication output for non-STEM students in science programs showed steady expansion from 2017 to 2021, followed by stabilization after 2019 and a modest decline in average citations from 2024 to 2025. This pattern suggests that the field has reached a stage of consolidation, where thematic maturity may be balancing growth. The lower citation averages in 2024–2025 reflect the natural recency effect, as newer publications have had limited time to accumulate citations. This steady growth indicates that interest in non-STEM participation in science education has expanded in response to global calls for inclusive and interdisciplinary teaching. The post-2020 citation surge aligns with the pandemic-driven shift toward digital learning environments, underscoring how institutional adaptation and technological innovation have become central themes in recent scholarship.

Table 3. Authors' Production Over Time

Author	No. of articles	Share of total (31)	Article Titles
Brownell S.E.	3	9.7%	Toward a conceptual framework for measuring the effectiveness of course-based undergraduate research experiences in biology Undergraduate biology lab courses: comparing traditional labs and authentic research experiences. Science Communication to the General Public: Why We Need to Teach Undergraduate and Graduate Students this Skill as Part of Their Formal Scientific Training.
Cooper K.M.	3	9.7%	The impact of active learning practices on student anxiety in undergraduate science classrooms. Student anxiety and fear of negative evaluation in active learning science classrooms. Student support and perceived belongingness in undergraduate science courses: A multi-institutional study.
Busch C.A.	3	9.7%	Conceptualizing community scientific literacy: Results from a systematic literature review and a Delphi method survey of experts. Effective strategies for learning and teaching in times of science denial and disinformation. The making of an outdoor educator: A mixed methods study of identity through voice and discourse.
Barboza L.	2	6.5%	Effect of data science teaching for non-STEM students: A systematic literature review. The effect of data science teaching for non-STEM students.
Maloshonok N.	1	3.2%	Do student engagement patterns differ across national higher education systems? The comparison of US, Chinese, and Russian high-level research-intensive universities.
Agboola B.M.	1	3.2%	Bringing literacy focus into the science classroom.
Aguilera R.	1	3.2%	What Effects Do Didactic Interventions Have on Students' Attitudes Towards Science? A Meta-Analysis.
Alhazzaa K.	1	3.2%	ENERGYSIM: techniques for advancing building energy education through immersive virtual reality (VR) simulation.
Alt D.	1	3.2%	Science Teachers' Conceptions of Teaching, Attitudes Toward Testing, and Use of Contemporary Educational Activities and Assessment Tasks
Amiruddin M.Z.B.	1	3.2%	Bibliometric Investigation in Misconceptions and Conceptual Change Over Three Decades of Science Education.

Table 2 depicts the productivity and impact of leading authors in research on non-STEM students in science education. A few scholars, such as Brownell, Cooper, and Busch, with three publications each, account for multiple high-impact publications, as shown by the largest circles in 2024, which together account for 9.7% of all publications. Barboza has two publications with 6.5%, while Maloshonok, Agboola, Aguilera, Alhazzaa, Alt, and Amiruddin each have one publication. This concentration suggests the need to diversify authorship through collaborative mentoring programs and international partnerships, fostering a more inclusive and globally representative research network. The clustering of authors from education and engineering backgrounds highlights how collaboration across disciplinary boundaries is driving the field. This cross-disciplinary authorship pattern suggests that institutions encouraging joint projects between education and STEM faculties may be better positioned to produce impactful research on non-STEM learners. The dominance of a few authors indicates the need for broader faculty engagement and training in inclusive science pedagogy across institutions.

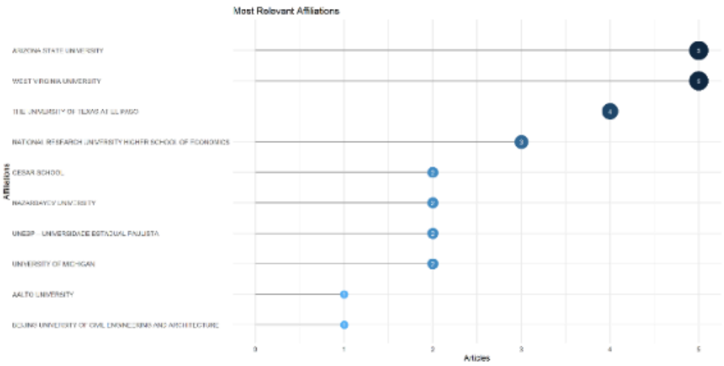

Figure 3. Institutional Productivity in Non-STEM Science Education Research

Figure 3 presents the leading institutions contributing to research on non-STEM students in science programs. Institutional data indicate that Arizona State University and West Virginia University have the highest number of documents with 5 or 16.1 % publications, followed by the University of Texas at El Paso, with four articles or 12.9% publications, the National Research University Higher School of Economics with three articles or 9.7% publications, Cesar School, Nazarbayev University, UNESP and University of Michigan with two articles or 6.5% publications. These institutions account for 27 of 31 articles, or 87.1% of the total contribution. Of all publications, confirming that output is clustered in a small set of universities. Institutions from North America, Europe, and Latin America are represented, while few from other regions meet the minimum publication threshold.

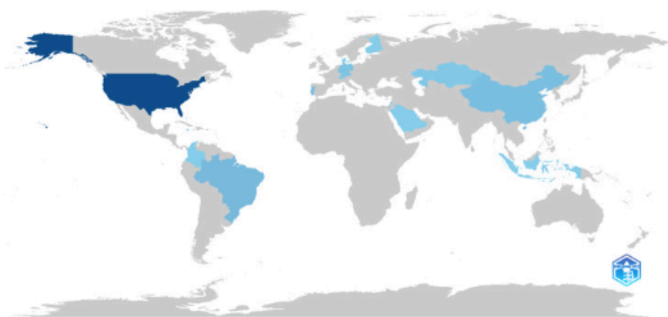

Figure 4. Country Scientific Production in Non-STEM Science Education Research
Legend:
Dark Blue: Highest publication output; Medium Blue: Moderate output; Light Blue: Emerging or low output

Figure 4 visualizes the global distribution of research output on non-STEM students in science programs. Country-level production shows that the United States has the most significant number of documents and citations in the dataset, with Hong Kong, Germany, Brazil, and China following at lower levels. A small number of countries contribute one or two publications each, and several regions have no qualifying documents, indicating a highly skewed geographic distribution of research activity.

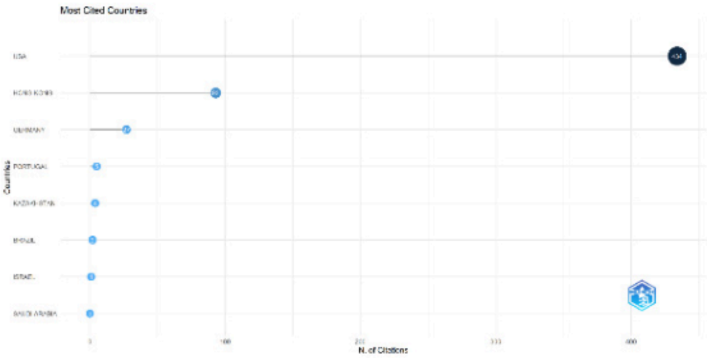

Figure 5. Most Cited Countries in Non-STEM Science Education Research

Figure 5 highlights the top-cited countries contributing to research on non-STEM students in science programs. The United States maintains the highest overall citation count, followed by Hong Kong, Germany, and Brazil. When adjusted for output volume, Hong Kong demonstrates the strongest citation-per-publication ratio, indicating a smaller but highly influential research base. High citations in smaller regions, such as Hong Kong, suggest a focus on quality rather than quantity, reflecting institutional efforts and strong international visibility. This trend also highlights the importance of regional specialization and global collaboration in advancing the field. High citation impact from a few countries may influence which pedagogical models are adopted internationally, potentially overlooking context-specific approaches needed in other education systems.

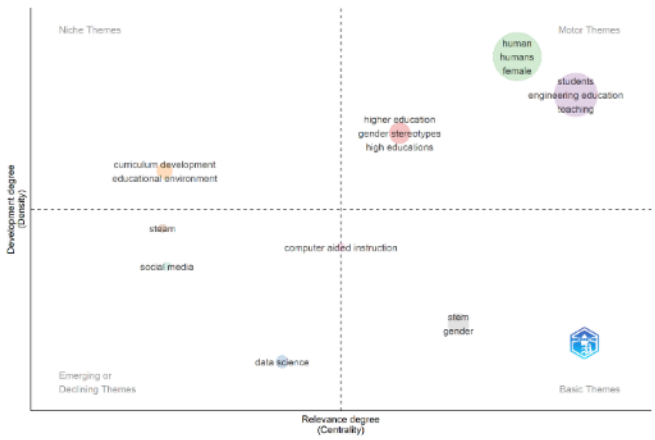

Figure 6. Thematic Map Visualizing Keyword Clusters Based on Dimensions
Legend:
Motor Themes – Central and well-developed (e.g., STEM education, teaching, students);
Basic Themes – Foundational topics supporting broader research (curriculum, assessment);
Emerging/Declining Themes – Developing or fading focus areas (motivation, gender);
Niche Themes – Specialized but less integrated (engineering education, laboratory learning)

The thematic map positions clusters along the x-axis by centrality (relevance) and the y-axis by density (development). In the upper-right quadrant, "students–engineering education–teaching" and "human–humans–female" appear as motor themes because they combine high centrality and high density, indicating that they are both conceptually central and internally well developed in the corpus. The lower-right quadrant contains "STEM–gender" as a basic theme, characterized by high centrality but lower density, suggesting that it is widely connected to other topics but less specialized.

In the upper-left quadrant, "curriculum development–educational environment" forms a niche theme with high density but low centrality, reflecting a well-developed but more peripheral area of research. The lower-left quadrant groups "STEAM," "social media," and "data science" as emerging or declining themes, all showing low centrality and low density, which indicates that these topics are either newly appearing in the literature on non-STEM students or not yet integrated into the central research front.

The thematic map identifies four categories of themes based on centrality and density. Motor themes, such as "non-STEM students," "active learning," and "learning outcomes," have high centrality and density, indicating that they are both conceptually central and well developed. Basic themes, including "science literacy," "general education," and "attitudes," show high centrality but lower density, functioning as broad, connecting concepts with less internal specialization.

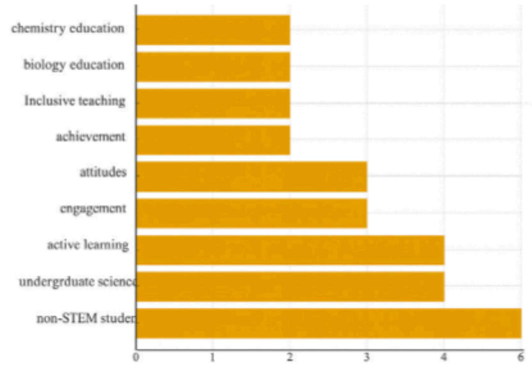

Figure 7. Top Author Keywords Appearing in Research on Non-STEM Students in Undergraduate Science Programs

The most frequent author keywords are "non-STEM students" (6 occurrences), "non-science majors" and "undergraduate science" (5 each), followed by "active learning" and "engagement" (4 each), and "attitudes," "achievement," "inclusive teaching," "biology education," and "chemistry education" (3 each).

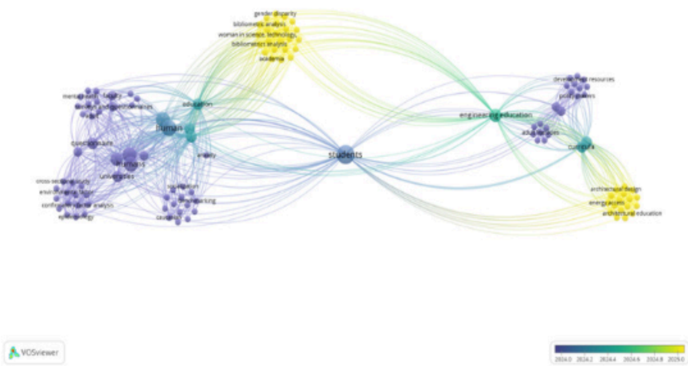

Figure 8. Keyword Co-occurrence Network in Non-STEM Science Education Research
Legend:
Blue nodes: Earlier research themes (around 2020–2022); Green nodes: Transitional themes (2023–2024); Yellow nodes: Recent or emerging themes (2025)

The overlay visualization shows that the yellow cluster appears only in the most recent time slice (2024–2025) and groups keywords such as "policy," "gender disparity," "woman in science, technology," "academia," "curricula," and "architectural education." This cluster is smaller and less densely connected than the central "students–human–engineering education" clusters, indicating that policy-oriented, gender-related, and curriculum-innovation topics form an emerging research front rather than a dominant theme in the corpus.

The observed concentration of publications, authors, and institutions in a small number of research-intensive systems aligns with previous bibliometric work in STEM and science education that reported similar dominance by high-income countries and well-resourced universities. In the context of non-STEM undergraduates, this pattern suggests that most evidence about their performance and learning experiences is generated in a narrow set of systems, echoing earlier concerns in the literature review about limited cross-country coverage and sparse representation from the Global South.

The thematic and keyword structures confirm that the field's core remains centered on course-level variables such as achievement, engagement, and teaching approaches, as highlighted in prior studies on general education and "science for non-science majors." At the same time, the position of equity-related terms (e.g., gender, disability) in basic, emerging, or low-density clusters supports the claim in the introduction that gender and broader human-capability dimensions remain weakly integrated into mainstream research on non-STEM students in science programs.

Finally, the late appearance of the yellow cluster, with its focus on policy, gender disparity, and curriculum innovation in 2024–2025, corresponds to the recent wave of studies that began to frame non-STEM learners' experiences within institutional and structural perspectives rather than solely at the classroom level. This temporal pattern reinforces the identified gaps by showing that policy- and equity-oriented analyses are only now beginning to form a visible, though small, research front, leaving substantial room for further empirical work in these areas.

Table 3. Summary of Core Bibliometric Indicators

Dimension	Item (examples from dataset)	Indicator reported	Bibliometric pattern focus
Top authors	Brownell S.E.; Cooper K.M.; Busch C.A.; Barboza L.; Maloshonok N.; Agboola B.M.; Aguilera R.; Alhazzaa K.; Alt D.; Amiruddin M.Z.B.	Number of articles per author; share of total output (e.g., top 4 authors = 11/31 articles = 35.5%)	Shows a concentrated authorship structure, with a small core group producing a large share of publications.
Top journals	CBE Life Sciences Education; European Journal of Engineering Education; Frontiers in Psychology; ACM International Conference Proceedings Series; PLOS ONE	Articles per journal; journal h-index within dataset; total citations per journal	Reveals that a limited set of journals accounts for most documents and citations, indicating preferred outlets for research on non-STEM students in science programs.
Top countries	United States; Hong Kong; Germany; Brazil; China	Number of articles per country, total citations, citations per article.	Indicates that both publication output and citation impact are heavily concentrated in a small set of countries (United States, Hong Kong, Germany, Brazil, China), revealing a geographically skewed research landscape in which evidence on non-STEM students' science learning is produced mainly in a few research-intensive systems.

CONCLUSION

This bibliometric review demonstrates that research on non-STEM students in undergraduate science programs remains a small but steadily expanding niche, evidenced by 31 Scopus-indexed publications from 2017 to 2025 and a 9.06% annual growth rate. Findings show that productivity and citation impact are concentrated within a small group of authors, institutions, and countries, particularly the United States, Hong Kong, Germany, Brazil, and China. At the same time, thematic patterns reveal a dominant focus on course-level outcomes, such as performance, engagement, and teaching approaches. In contrast, topics related to policy, equity, and gender appear only as emerging, low-density themes, indicating that these areas have yet to gain central visibility in the field. With co-occurrence data showing that equity-oriented constructs have emerged mainly in recent years, there remains substantial room for expansion toward more inclusive, policy-responsive science education research. This study is limited to Scopus and English-language sources, potentially excluding regional and non-English-language literature. Therefore, future research should incorporate multiple databases, foster cross-regional collaborations, and prioritize equity-focused investigations to capture diverse contexts. These findings further imply that curriculum designers, educators, and policymakers must strengthen instructional support for non-STEM undergraduates and develop inclusive strategies aligned with SDG 4 to ensure that no learner group remains underserved in science education.

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