

Science Education and Its Challenges: A Bibliometric Analysis of Global Research Trends (2010–2025)

Siti Hasmah Binti Amat Baking, Sabariah Sharif, Aidan Norman Lanjat and Anjaleen Francis

Abstract- This study provides a bibliometric analysis of global research on science education and its challenges from 2010 to 2025, examining publication growth, intellectual structure, and thematic evolution within the field. Growing interest in science education has been driven by rapid technological change, policy reform, and increasing demands for inclusive and resilient pedagogical practices, particularly following widespread educational disruption after 2020. Bibliographic data were retrieved from the Scopus database and analysed using citation analysis, keyword co-occurrence, and institutional mapping. VOSviewer software was employed to visualise collaboration networks, co-citation structures, and thematic clusters. The findings indicate a sustained increase in research output, with a pronounced acceleration after 2020. The United States, the United Kingdom, and Germany emerged as the most influential contributors, while research from South Africa, Brazil, and Spain offered critical perspectives on equity, access, and contextual challenges in science education. Leading institutions, including Michigan State University, Universiteit Utrecht, and the University of Edinburgh, were identified as central nodes in global research networks. Thematic analysis revealed dominant clusters focused on teacher professional development, digital and technology-enhanced learning, STEM education, and equity-related challenges in rural and underserved contexts. Overall, the results demonstrate that science education research is expanding in both scale and thematic complexity, reflecting global efforts to align educational practices with digital transformation, inclusivity, and workforce preparedness. Future research should prioritise greater representation from underexplored regions, examine the pedagogical implications of emerging technologies such as artificial intelligence and virtual reality, and strengthen international collaboration to support contextually responsive and globally relevant science education.

Keywords – Science education, Bibliometric analysis, STEM education, Rural education challenges, Global research collaboration, Sustainable STEM education

I. INTRODUCTION

The importance of science education in rural schools cannot be overstated, given its essential role in fostering scientific literacy, supporting sustainable development, and preparing students for participation in a technology-driven workforce. Rural schools, which serve nearly nine million students in the United States alone, face persistent

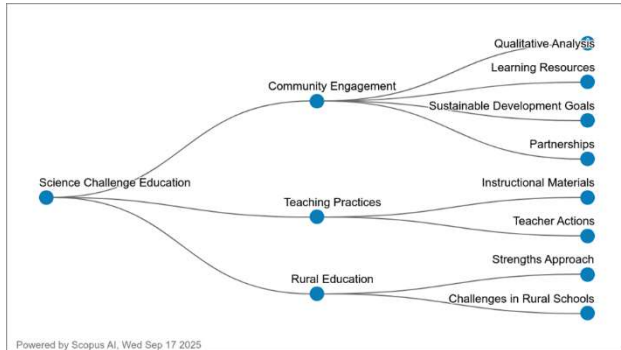
structural and contextual challenges that significantly affect the quality and accessibility of science education (Broneak & Rosato, 2021). These challenges include difficulties in recruiting and retaining qualified STEM teachers, limited funding allocations, and restricted access to critical resources such as laboratory facilities and broadband internet connectivity (Broneak & Rosato, 2021). Despite these constraints, rural schools possess unique strengths, including close community ties and locally grounded contexts, which can be leveraged to deliver meaningful and relevant science learning experiences (Murphy, 2022). This section examines the significance of science challenge education in rural schools, with particular attention to existing barriers and strategic approaches for effective implementation.

Science challenge education, which engages students in authentic, inquiry-driven, and community-based science projects, offers a promising framework for strengthening science education in rural contexts. By connecting scientific concepts to real-world problems, this approach enhances student engagement, conceptual understanding, and learning outcomes (Blake & Campbell, 2009). Empirical evidence from initiatives such as the Learning by Making (LbyM) programme demonstrates that integrating computational thinking with locally relevant STEM applications can significantly improve students' self-efficacy and sustained interest in science (Li et al., 2024). Furthermore, science challenge education contributes to educational equity by narrowing the opportunity gap between rural and urban learners through access to high-quality, contextually responsive STEM experiences (Li et al., 2024). This pedagogical approach aligns with broader rural development and sustainability goals by equipping students with the skills and knowledge required to address local environmental, economic, and societal challenges (Qi, 2025).

Despite its potential, the implementation of science challenge education in rural schools is constrained by several systemic challenges. Rural teachers frequently experience professional isolation, limited access to instructional materials, and insufficient opportunities for continuous professional development, all of which impede the delivery of effective science instruction (Zinger et al., 2020; North & Rose, 2025). In addition, smaller school sizes and restricted resources often limit curriculum breadth and the provision of diverse learning pathways, making it difficult to maintain high academic standards (Murphy, 2022; Panizzon, 2011). Addressing these challenges requires targeted and context-sensitive policy interventions. Key strategies include strengthening teacher professional development in inquiry-based and project-based pedagogies, leveraging community partnerships and local expertise to enrich science learning, and increasing institutional support and funding for rural education

Siti Hasmah BT Amat Baking, University of Malaysia, Malaysia (dsitihasmah@gmail.com).
Sabariah BT Sharif, University of Malaysia, Malaysia (sabariahsharif@gmail.com).
Aidan Norman Lanjat, University of Tunku Abdul Rahman (UNITAR), Malaysia (aidannfl@gmail.com).
Anjaleen Francis, University of Tunku Abdul Rahman (UNITAR), Malaysia (anjaleen@gmail.com)

initiatives (Murphy, 2022; Qi, 2025; Morales et al., 2022). Through coordinated efforts among policymakers, educators, and communities, rural schools can provide equitable and high-quality science education that supports students' academic achievement and long-term career aspirations.



II. PROBLEM STATEMENT

Despite the widely acknowledged importance of science education in fostering scientific literacy, sustainable development, and workforce readiness, rural schools continue to experience persistent challenges that undermine the quality and effectiveness of science teaching and learning. Structural constraints such as shortages of qualified STEM teachers, limited funding, inadequate instructional resources, and restricted access to digital infrastructure remain prevalent in rural contexts, resulting in unequal science learning opportunities when compared to urban schools. Although rural schools possess strong community ties and locally grounded contexts that could potentially enrich science education, these strengths are often underutilised within conventional instructional models.

In response to these challenges, science challenge education—characterised by inquiry-based, community-oriented, and problem-solving approaches—has been proposed as a promising pedagogical strategy for enhancing student engagement and contextual relevance in rural science education. However, existing research on science challenge education in rural schools remains fragmented, with many studies focusing on isolated programmes, short-term interventions, or specific geographical contexts. There is limited empirical evidence examining how science challenge education can be systematically implemented and sustained within rural school settings, particularly in relation to teacher capacity, instructional practices, and equity in student access to high-quality science learning experiences.

Furthermore, while prior studies have highlighted the potential of community partnerships and contextual learning to support science education, there is a lack of integrative research that synthesises the interplay between pedagogical strategies, teacher professional development, and systemic support mechanisms in rural contexts. This gap underscores the need for comprehensive research that examines the challenges, enabling factors, and implementation strategies of science challenge education

in rural schools. Addressing this gap is essential to inform policy, guide instructional innovation, and ensure that rural students are provided with equitable, meaningful, and future-oriented science education.

III. LITERATURE REVIEW

Science education in rural school contexts has been widely recognised as a critical component in promoting scientific literacy, socio-economic development, and equitable access to STEM opportunities. Rural schools often operate within unique socio-cultural and geographical environments that shape teaching practices, curriculum delivery, and student engagement (Murphy, 2022). Despite serving large student populations globally, rural schools continue to experience persistent disparities in science education outcomes when compared to urban counterparts, largely due to systemic challenges such as limited infrastructure, teacher shortages, and reduced access to instructional resources (Zinger et al., 2020; Broneak & Rosato, 2021). These structural constraints have significant implications for the quality of science instruction and the sustainability of STEM initiatives in rural settings.

Concept and Significance of Science Challenge Education

Science challenge education refers to pedagogical approaches that engage learners in authentic, inquiry-based, and problem-oriented activities grounded in real-world and community contexts. This approach emphasises active learning, critical thinking, and the application of scientific knowledge to address locally relevant issues (Blake & Campbell, 2009). Prior studies indicate that science challenge education enhances students' motivation, conceptual understanding, and scientific reasoning by connecting classroom learning with meaningful societal and environmental challenges (Li et al., 2024). In rural schools, where contextual relevance plays a crucial role in student engagement, science challenge education has been identified as a particularly effective strategy for fostering deeper learning and sustained interest in science.

Equity and Access in Rural Science Education

Educational equity remains a central concern in rural science education research. Rural students frequently face limited exposure to advanced science courses, laboratory experiences, and technology-enhanced learning environments, resulting in disparities in STEM participation and achievement (Murphy, 2022; Panizzon, 2011). Science challenge education has been proposed as a mechanism to mitigate these inequities by offering flexible, community-based learning opportunities that do not rely solely on conventional laboratory infrastructure (Li et al., 2024). By leveraging local resources, environmental contexts, and community expertise, this approach supports inclusive learning experiences that are responsive to the needs of rural learners.

Teacher Capacity and Professional Development

Teacher capacity is a critical determinant of effective science challenge education implementation in rural schools. Research consistently highlights that rural teacher often experience professional isolation, limited access to specialised training, and fewer opportunities for collaborative learning, which can constrain pedagogical innovation (Zinger et al., 2020; North & Rose, 2025). Effective science challenge education requires teachers to possess strong pedagogical content knowledge, inquiry facilitation skills, and confidence in integrating interdisciplinary STEM practices. Targeted professional development programmes and collaborative networks have been identified as essential strategies for enhancing rural teachers' instructional capacity and sustaining innovative science teaching practices (Morales et al., 2022).

Community Partnerships and Contextual Learning

Community engagement and partnerships play a pivotal role in the success of science challenge education in rural settings. Studies suggest that collaborations with local industries, environmental agencies, and community organisations enrich science learning by providing authentic contexts and real-world relevance (Blake & Campbell, 2009; Qi, 2025). Such partnerships not only strengthen students' understanding of scientific concepts but also foster a sense of place-based responsibility and community identity. Integrating community-based challenges into science curricula has been shown to enhance students' problem-solving skills and awareness of local sustainability issues.

Research Gaps and Future Directions

Despite growing scholarly interest, existing literature on science challenge education in rural schools remains fragmented and context-specific. Many studies focus on isolated programmes or short-term interventions, with limited longitudinal evidence on sustained impact and scalability. Furthermore, there is a lack of comprehensive synthesis examining how science challenge education intersects with teacher professional development, equity, and policy implementation in diverse rural contexts. Future research should adopt mixed-method and longitudinal designs to evaluate long-term learning outcomes, explore cross-country comparisons, and examine the role of emerging technologies in supporting science challenge education in rural schools.

Technology has brought a drastic change in the world and has revolutionized education. With a range of possible solutions to develop EFL learning, technology has become a successful medium for practicing English conversation. Additionally, technology is also able to present authentic situations where learners unable to see in real life situations (Diyab, 2014). With the massive growth of online conversation platforms, it becomes easier for language learners to practice English with people from other countries.

In terms of online conversation platforms, Wakefield & Rice (2008) point out that text messaging, instant messaging, chat rooms, and personal web sites have increased the speed of multiple and simultaneous interaction. Based on this fact, it is indispensable to take advantage of modern technological facilities in aiding the task of English language practices (Hwang, Huang, Shadiev, Wu, & Chen, 2014). This technology provides many new potential channels for promoting English conversation among people who live in different countries (Wu, Yen & Marek, 2011). Among online conversation platforms, there is one type of platforms that replicates a real-world situation, which known as 3D Virtual Worlds.

IV. METHOD

Bibliometrics involves gathering, organizing, and analyzing bibliographic data from scientific publications (Alves et al., 2021; Assyakur & Rosa, 2022; Verbeek et al., 2002). Beyond basic statistics, such as identifying publishing journals, publication years, and leading authors (Wu & Wu, 2017), bibliometrics includes more sophisticated techniques like document co-citation analysis. Conducting a successful literature review requires a careful, iterative process to select suitable keywords, search the literature, and perform an in-depth analysis. This approach helps to compile a comprehensive bibliography and achieve reliable results (Fahimnia et al., 2015). With this in mind, the study focused on high-impact publications, as they provide meaningful insights into the theoretical frameworks that shape the research field. To ensure data accuracy, SCOPUS served as the primary source for data collection (Al-Khoury et al., 2022; di Stefano et al., 2010; Khiste & Paithankar, 2017). Additionally, to maintain quality, the study only considered articles published in peer-reviewed academic journals, deliberately excluding books and lecture notes (Gu et al., 2019). Using Elsevier's Scopus, known for its broad coverage, publications were collected from 2020 through December 2023 for further analysis."

TABLE 1: THE SEARCH STRIN

TITLE	(Science AND Challenges) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (SUBJAREA , "SOCI")) TITLE (Science AND Challenges) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (SUBJAREA , "SOCI")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English"))
Scopus	PUBYEAR > 2009 AND PUBYEAR < 2026 AND (LIMIT-TO (SUBJAREA, "SOCI")) AND (LIMIT-TO (LANGUAGE , "English"))

TABLE II: SEARCH SELECTION CRITERIA

Criterion	Inclusion	Exclusion
Language	English	Non-English
Time line	2010-2025	< 2009
Publication Stage	Final	In Press
Subject Area	Social Science	Computer Science

Data analysis

VOSviewer is a user-friendly bibliometric software developed by Nees Jan van Eck and Ludo Waltman at Leiden University, Netherlands (van Eck & Waltman, 2010, 2017). Widely utilized for visualizing and analyzing scientific literature, the tool specializes in creating intuitive network visualizations, clustering related items, and generating density maps. Its versatility allows for the examination of co-authorship, co-citation, and keyword co-occurrence networks, providing researchers with a comprehensive understanding of research landscapes. The interactive interface, coupled with continuous updates, ensures efficient and dynamic exploration of large datasets. VOSviewer's ability to compute metrics, customize visualizations, and its compatibility with various bibliometric data sources make it a valuable resource for scholars seeking insights into complex research domains.

One of the standout features of VOSviewer is its capacity to transform intricate bibliometric datasets into visually interpretable maps and charts. With a focus on network visualization, the software excels in clustering related items, analyzing keyword co-occurrence patterns, and generating density maps. Researchers benefit from its user-friendly interface, enabling both novice and experienced users to explore research landscapes efficiently. VOSviewer's continuous development ensures it remains at the forefront of bibliometric analysis, offering valuable insights through metrics computation and customizable visualizations. Its adaptability to different types of bibliometric data, such as co-authorship and citation networks, positions VOSviewer as a versatile and indispensable tool for scholars seeking deeper understanding and meaningful insights within their research domains.

Datasets comprising information on the publication year, title, author name, journal, citation, and keywords in PlainText format were procured from the Scopus database, spanning the period from 2004 to December 2024. These datasets were then analyzed using VOSviewer software version 1.6.19. Through the application of VOS clustering and mapping techniques, this software facilitated the examination and generation of maps. Offering an alternative to the Multidimensional Scaling (MDS) approach, VOSViewer focuses on situating items within low-dimensional spaces, ensuring that the proximity between any two items accurately reflects their relatedness and similarity (van Eck & Waltman, 2010). In this respect, VOSViewer shares a similarity with the MDS approach (Appio et al., 2014). Diverging from MDS, which primarily engages in the computation of similarity metrics

like cosine and Jaccard indices, VOS utilizes a more fitting method for normalizing co-occurrence frequencies such as, the associatio strength (AS_{ij}) and it is calculated as (Van Eck & Waltman, 2007):

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

which is “proportional to the ratio between on the one hand the observed number of cooccurrences of i and j and on the other hand the expected number of co-occurrences of i and j under the assumption that co-occurrences of i and j are statistically independent” (Van Eck & Waltman, 2007).

V. FINDINGS

What are the trend / What are the research trends in Science Education and Challenges according to the year of publication?

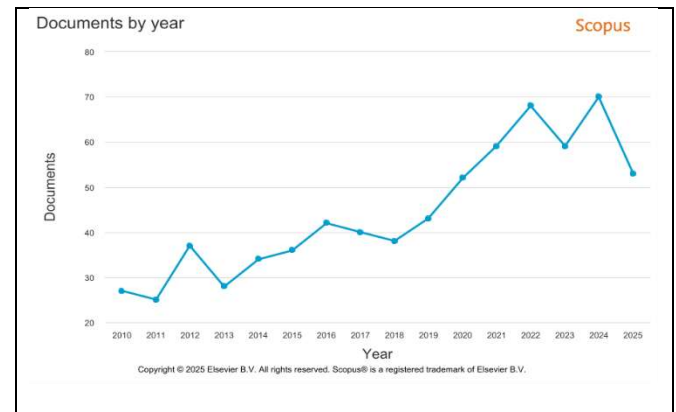


TABLE 3 : TREND OF RESEARCH IN SCIENCE EDUCATION AND CHALLENGES BY YEARS OF PUBLICATION

Number of results : 711		
YEAR	TOTAL Publication	Percentage (%)
2025	53	7
2024	70	10
2023	59	8
2022	68	10
2021	59	8
2020	52	7
2019	43	6
2018	38	5
2017	40	6
2016	42	6
2015	36	5
2014	34	5
2013	28	4
2012	37	5
2011	25	4
2010	27	4

The bibliometric analysis of 711 publications on Science Education and its challenges from 2010 to 2025 reveals a dynamic growth trajectory. The annual distribution shows fluctuations but an overall upward trend in research productivity. The earliest years (2010–2013)

recorded relatively modest outputs ranging between 25–28 publications per year ($\approx 4\%$), reflecting a formative phase of scholarly attention toward science education issues. From 2014 to 2019, the volume steadily increased, averaging 5–6% of the total, which indicates a gradual recognition of science education as a significant research domain. This period can be seen as a transition phase where global educational reforms and digital technology adoption began to influence research direction.

The period between 2020 and 2025 demonstrates a noticeable surge in publication activity, with each year consistently contributing between 7–10% of the total output. This increase coincides with the global COVID-19 pandemic, which accelerated discourse on digital learning, online pedagogy, and challenges in ensuring equitable access to science education. Notably, 2024 recorded the highest output (70 publications; 10%), reflecting intensified research efforts in understanding the implications of technology integration, STEM policies, and pedagogical adaptation. The 2025 figures (53 publications; 7%) suggest sustained momentum, though slightly lower than the peak, possibly reflecting stabilization after the initial post-pandemic surge.

Overall, the bibliometric trend underscores a shift in research priorities from foundational issues in science education to more complex challenges, such as inclusivity, digital divide, and STEM career readiness. The rise in output over the last five years demonstrates a global alignment of science education research with contemporary challenges, including sustainability, technological advancement, and policy implementation. This pattern indicates that science education scholarship is not only expanding in volume but also becoming increasingly responsive to global educational transformations, with strong implications for future practice and policymaking.

Who and how much has been published in the area with regard to the authors, their affiliated organisations and countries?

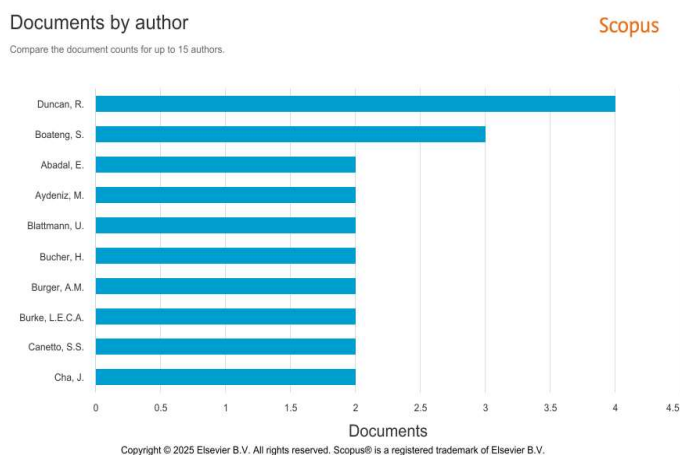


TABLE IV : TREND OF RESEARCH IN SCIENCE EDUCATION AND CHALLENGES BY TOP AUTHOR

AUTHOR NAME	
Duncan, R.	4
Boateng, S.	3
Abadal, E.	2
Aydeniz, M.	2
Blattmann, U.	2
Bucher, H.	2
Burger, A.M.	2
Burke, L.E.C.A.	2
Canetto, S.S.	2
Cha, J.	2

The bibliometric analysis of author productivity in the field of Science Education and Challenges demonstrates a diverse contribution pattern with a relatively small group of prolific authors leading research output. Among the listed scholars, Duncan, R. emerges as the most active, contributing four publications, indicating his strong engagement and consistent presence in shaping discourse within this domain. His higher output compared to others suggests a central role in advancing theoretical perspectives or empirical evidence, potentially making him a key influencer in the field’s intellectual development.

Following Duncan, Boateng, S. has produced three publications, while a cluster of authors—including Abadal, E., Aydeniz, M., Blattmann, U., Bucher, H., Burger, A.M., Burke, L.E.C.A., Canetto, S.S., and Cha, J.—each contributed two publications. This pattern reflects the “long-tail” phenomenon often seen in bibliometric studies, where a few scholars contribute more significantly while the majority contribute at moderate levels.

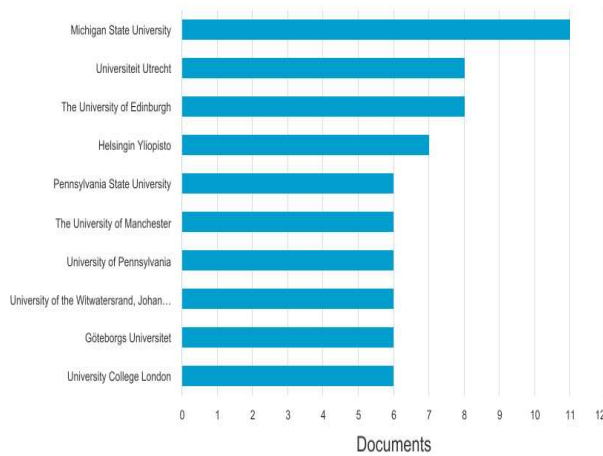
The balanced presence of multiple authors with two publications each also suggests a healthy diversification of perspectives, methodologies, and geographic representation, which enriches the knowledge base on science education challenges.

The data further highlights that while no single author dominates the field extensively, the collective contributions reflect an emerging and collaborative research landscape. The distribution of authorship suggests that science education challenges are being explored from multiple cultural, policy, and pedagogical lenses rather than monopolized by a few researchers. This diversity of authorship not only ensures that the discourse remains inclusive but also creates opportunities for interdisciplinary connections and global knowledge sharing. It indicates that future research directions may lean towards increased collaboration, with these moderately productive authors likely serving as anchors for new networks and thematic clusters.

Documents by affiliation

Compare the document counts for up to 15 affiliations.

Scopus



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TABLE V :TREND OF RESEARCH IN SCIENCE EDUCATION AND CHALLENGES BY TOP AFFILIATION

AFFILIATION	
Michigan State University	11
Universiteit Utrecht	8
The University of Edinburgh	8
Helsingin Yliopisto	7
Pennsylvania State University	6
The University of Manchester	6
University of Pennsylvania	6
University of the Witwatersrand, Johannesburg	6
Göteborgs Universitet	6
University College London	6

The affiliation analysis indicates that research on Science Education and Challenges is concentrated within leading universities across North America, Europe, and Africa, reflecting a globalized but institutionally clustered scholarly landscape. Michigan State University leads with 11 publications, positioning itself as a central hub for advancing science education research, possibly due to its strong emphasis on STEM policy and teacher education. European institutions such as Universiteit Utrecht and The University of Edinburgh (8 publications each), along with Helsingin Yliopisto (7), highlight the continent’s active engagement in addressing science education challenges through diverse pedagogical and policy-driven approaches. Prominent U.S. universities, including Pennsylvania State University, University of Pennsylvania, and The University of Manchester (6 publications each), further emphasize the country’s pivotal role in shaping research on inclusivity, technology

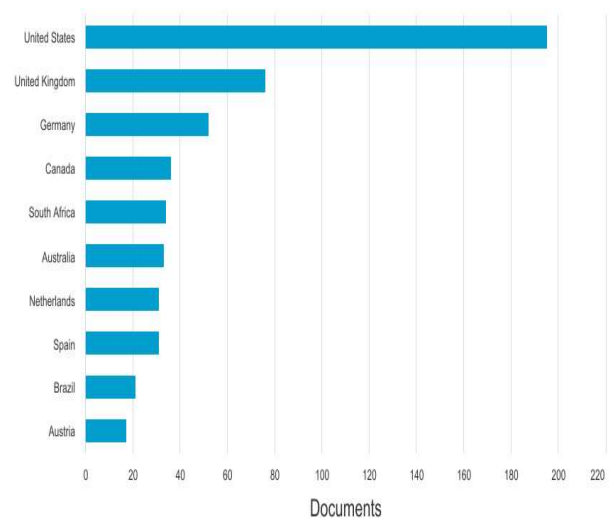
integration, and educational reform. Notably, the presence of University of the Witwatersrand, Johannesburg with 6 publications underscores the growing importance of African scholarship in contributing to global discourses on science education, particularly within contexts of inequality and resource constraints.

This distribution suggests that while the field is international in scope, research leadership is concentrated among well-established institutions with strong academic infrastructures and global collaboration networks.

Documents by country or territory

Compare the document counts for up to 15 countries/territories.

Scopus



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Created with mapchart.net

TABLE VI: TREND OF RESEARCH IN SCIENCE EDUCATION AND CHALLENGES BY COUNTRY

COUNTRY/TERRITORY	
United States	195
United Kingdom	76
Germany	52
Canada	36
South Africa	34
Australia	33
Netherlands	31
Spain	31
Brazil	21
Austria	17

The Scopus data indicates that the United States leads significantly in publications, contributing 195 articles, which is more than double the number of the second-highest contributor, the United Kingdom with 76 publications. This dominance reflects the strong research infrastructure, extensive funding, and established academic networks in the United States, particularly in fields related to science education and its associated challenges. The United Kingdom and Germany (52 publications) follow, showing Europe’s substantial role in advancing scholarly discussions on this theme. These countries’ outputs highlight their emphasis on integrating technology, pedagogical innovation, and policy-driven research within education.

Middle-tier contributors such as Canada (36), South Africa (34), and Australia (33) also play a vital role in shaping global perspectives. South Africa’s presence among the top contributors is particularly noteworthy, as it signals increasing engagement from the Global South in educational research, often bringing attention to issues of equity, access, and socio-economic disparities. Canada and Australia, known for their progressive educational reforms, appear to be investing heavily in exploring new strategies for improving learning outcomes and addressing systemic challenges in education.

Meanwhile, the Netherlands and Spain, with 31 publications each, along with Brazil (21) and Austria (17), reflect a growing but more regionally concentrated research effort. Brazil’s inclusion highlights Latin America’s contributions, often tied to local challenges in under-resourced educational contexts, while Austria’s presence shows the involvement of smaller European nations in high-quality research. Collectively, the distribution demonstrates that while research is heavily concentrated in developed nations, there is increasing visibility from emerging regions, pointing toward a more inclusive and global dialogue on science education and its challenges.

VI. DISCUSSION

This study provides a comprehensive bibliometric overview of research trends in *Science Education and its Challenges* from 2010 to 2025, offering insights into temporal growth patterns, authorship dynamics, institutional leadership, and geographical distribution. The discussion interprets these findings in relation to global

educational developments, theoretical implications, and research priorities in science education.

Evolution of Research Trends in Science Education and Challenges

The upward trajectory observed in publication output over the 15-year period reflects a growing scholarly recognition of science education as a critical domain for addressing contemporary societal and technological demands. The relatively low publication volume between 2010 and 2013 suggests that early research primarily focused on foundational pedagogical issues, curriculum development, and traditional classroom practices. This phase aligns with earlier stages of global STEM awareness, where science education was often examined in isolation from broader systemic challenges.

The gradual increase from 2014 to 2019 marks a transition period in which science education research began integrating themes such as digital technology, inquiry-based learning, and teacher professional development. This shift coincides with international policy initiatives promoting STEM education, such as curriculum reforms and the integration of digital tools in classrooms. The steady growth during this period indicates an expansion in research scope rather than abrupt change, suggesting cumulative scholarly engagement.

The sharp rise in publications from 2020 onwards reflects a paradigm shift driven largely by the COVID-19 pandemic. The global disruption of education systems accelerated research on online learning, emergency remote teaching, digital inequities, and students’ engagement in science learning under constrained conditions. The peak observed in 2024 further suggests that post-pandemic reflections, evaluations of pedagogical resilience, and long-term implications of technology integration have become dominant research concerns. Overall, the findings indicate that science education research has evolved from addressing conventional instructional challenges to grappling with complex, systemic, and global issues such as equity, access, and sustainability.

Authorship Patterns and Knowledge Production

The authorship analysis reveals a dispersed yet collaborative research landscape, characterized by the absence of a single dominant scholar. While Duncan, R. emerges as the most prolific author, the relatively small differences in publication counts among top authors suggest that knowledge production in this field is shared across multiple contributors rather than concentrated within an elite group. This pattern reflects the interdisciplinary and context-dependent nature of science education research, where diverse perspectives are essential for addressing multifaceted challenges.

The presence of many authors contributing two to three publications supports the notion of a “distributed expertise” model, where researchers engage intermittently based on thematic relevance, institutional priorities, or collaborative projects. Such a structure enhances methodological diversity and promotes cross-cultural

insights, particularly important in education research where contextual factors play a significant role. This authorship pattern also indicates strong potential for future international collaboration and the formation of thematic research clusters addressing emerging challenges such as inclusive STEM education and digital pedagogy.

Institutional Leadership in Science Education Research

The dominance of well-established universities among top affiliations underscores the role of institutional capacity in driving high-impact research. Institutions such as Michigan State University, Universiteit Utrecht, and The University of Edinburgh are known for their strong emphasis on teacher education, STEM policy, and educational research infrastructure. Their prominence suggests that sustained funding, doctoral training programs, and international collaboration networks significantly influence research productivity.

However, the distribution of affiliations also reflects a degree of global inclusivity, particularly with the presence of the University of the Witwatersrand in South Africa. This indicates that institutions from developing contexts are increasingly contributing to global discussions, often focusing on challenges related to inequality, resource limitations, and systemic reform. The findings suggest that while research leadership remains concentrated in high-income institutions, the intellectual landscape of science education is gradually becoming more globally representative.

Geographical Distribution and Global Research Inequality

Country-level analysis highlights a pronounced dominance of the United States, which accounts for a substantial proportion of total publications. This leadership can be attributed to extensive research funding, established STEM initiatives, and strong academic publishing cultures. Similarly, the strong presence of the United Kingdom and Germany reflects Europe's strategic investment in education research and innovation.

The notable contributions from countries such as South Africa, Brazil, and Austria indicate increasing engagement beyond traditional research powerhouses. South Africa's position is particularly significant, as it reflects growing scholarly attention to science education challenges in contexts marked by socio-economic disparities and educational transformation. Nevertheless, the overall distribution reveals persistent global inequalities in research output, with underrepresentation from many developing regions, including parts of Asia and Africa.

This imbalance suggests that while science education challenges are global in nature, research narratives are still largely shaped by perspectives from developed countries. Addressing this gap is essential for developing context-sensitive solutions and ensuring that global science education policies are informed by diverse educational realities.

Implications for Future Research

The bibliometric patterns identified in this study suggest several implications for future research. First, the sustained post-pandemic research momentum indicates a need to move beyond descriptive studies toward evaluative and theory-driven investigations that assess the long-term effectiveness of digital and hybrid science education models. Second, increased collaboration across countries and institutions—particularly involving underrepresented regions—can enrich the field with diverse perspectives and locally grounded insights.

Finally, the evolution of research themes highlights the importance of aligning science education research with global priorities such as sustainability, equity, and workforce readiness. Future studies should therefore emphasize inclusive STEM practices, teacher capacity building, and policy implementation across diverse educational contexts.

VII. CONCLUSION (OR LIMITATION OR SUGGESTION FOR FURTHER STUDIES)

The Scopus analysis shows that the United States dominates with 195 publications, far ahead of the United Kingdom (76) and Germany (52), reflecting its strong funding systems, research infrastructure, and global academic networks in education-related studies. Middle-tier contributors such as Canada (36), South Africa (34), and Australia (33) highlight both developed and developing contexts, with South Africa's position being significant as it underscores the growing role of the Global South in addressing issues of equity and access in education. Meanwhile, countries like the Netherlands (31), Spain (31), Brazil (21), and Austria (17) add diversity to the global research landscape, showing that while publication outputs are concentrated in leading economies, emerging regions are increasingly contributing localized perspectives, particularly in addressing digital divides, socioeconomic disparities, and innovative approaches in science and STEM education.

This bibliometric analysis provides a comprehensive overview of research trends, influential contributors, and thematic developments in science education between 2010 and 2025. The findings indicate steady growth in publications, with a marked surge after 2020 as scholars responded to global disruptions and the increasing demand for digital pedagogical solutions. Research output is dominated by the United States, the United Kingdom, and Germany, while contributions from South Africa, Brazil, and Spain highlight critical issues of equity and access. Prominent institutions such as Michigan State University, Universiteit Utrecht, and the University of Edinburgh function as global research hubs, driving collaboration and knowledge dissemination.

Several recommendations emerge from this study. Future research should move beyond dominant regions by integrating perspectives from underrepresented contexts in Asia, Africa, and Latin America. There is also a need to explore the role of emerging technologies such as artificial intelligence, virtual reality, and adaptive systems in

shaping science education. Employing mixed method approaches that combine bibliometric mapping with empirical classroom research would generate more holistic insights. On the practical front, strengthening teacher training in digital pedagogy, promoting blended and inclusive learning models, and ensuring access to adaptive technologies are essential to improving classroom practices, particularly in rural and under-resourced settings.

The study also carries implications for theory, practice, and policy. Theoretically, it highlights the need to integrate established frameworks with new models of technology-enhanced learning. Practically, it reinforces the importance of continuous professional development and innovative pedagogy. At the policy level, addressing the digital divide, investing in ICT infrastructure, and aligning science education with workforce and sustainable development goals remain critical. Overall, science education research is becoming more diverse and globally relevant, offering opportunities to advance equity, innovation, and inclusivity in education.

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