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Exploring Research Trends in Science Education to be Implemented in the Elementary School

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Abstract

Through an extensive bibliometric analysis, this study explored the ever-changing field of science education. In-depth analyses of publishing patterns, journal contributions, researcher output, institutional partnerships, and theme content and developmental paths in the field of scientific studies education are all included in the objectives. An exhaustive search of Scopus was used to gather research data from 2000 to 2023. Keywords including learning, science education, and elementary school were found in article titles, abstracts, and keywords. Research patterns were examined using Vos Viewer software, yielding important discoveries. The findings revealed that the highest number of research publications in the field of science education indexed in Scopus was observed in 2023, with 195 publications. Most international publications in this field were found in journal articles, with the United States being the leading contributor. The co-word analysis of the science education learning field identified eight clusters encompassing 88 themes associated with its development. These findings highlight the importance of interdisciplinary collaboration, focused investment in research areas, and the promotion of evidence-based approaches to improving educational outcomes in elementary schools. therefore, influence future research directions, policy formulation, and educational practices and advance knowledge in the field of science education.

Keywords: Bibliometric, Elementary school, Science Education, Scopus database

INTRODUCTION

Elementary science education lays the foundation for students' comprehension of scientific ideas and developing their critical thinking abilities, preparing them for future academic endeavors and professional goals (Sellars et al., 2018). Considering the importance of science, teachers work hard to improve the caliber and efficacy of scientific education in primary schools. Keeping up with the most recent scientific research trends is crucial to this endeavor because it provides insightful information and evidence-based practices that can be used to guide curriculum creation and pedagogical techniques (Bybee, 2019). Murphy et al., (2021) study highlights the value of practical, inquiry-based approaches in promoting students' scientific knowledge and curiosity, emphasizing the significance of hands-on experience learning in primary science education. To improve the primary school learning experience, this

introduction seeks to give educators and stakeholders a thorough overview of new research trends in science education research.

Fostering scientific literacy and curiosity in elementary school pupils requires understanding the changing field of science education research (National Research Council, 2012). the study's research trends cover a broad spectrum of subjects, including curriculum design, instructional practices, technological integration, and fostering inclusion and fairness in the classrooms (Windschitl et al., 2018). By looking at these tendencies, teachers may learn a great deal about good teaching techniques, ways to engage students, and methods for developing young learners' conceptual comprehension and scientific inquiry abilities (Chen et al., 2020). Moreover, comprehension of research trends in science education research is necessary to match classroom methods with contemporary educational standards and frameworks (Darling-Hammond et al., (2020). Teachers must be current on the most recent research results and best practices in science teaching as educational policies change to match advancements in scientific understanding and pedagogy (Lederman & Lederman, 2019). This calls for a methodical approach to analyzing and synthesizing research literature, which may be made Educators may make evidence-based decisions about curriculum creation and instructional design by using these approaches to identify critical areas of attention, new trends, and gaps in the literature (Siuty et al., 2018)

Evidence-based practices—those supported by thorough study and actual data—have been increasingly important in scientific teaching in recent years (Alkhammash, 2023). To help educators and policymakers discover important themes, emerging trends, and areas of attention within the subject of scientific studies, bibliometric approaches provide a systematic framework for assessing and synthesizing the large body of literature in the discipline. Investigating cutting-edge educational strategies that foster student engagement, conceptual comprehension, and scientific literacy is one of the main goals of science education research (Madsen et al., 2023). Additionally, scientific studies research aims to accommodate students' varied needs and backgrounds to guarantee that all students have fair access to high-quality science education (NGSS Lead States, 2013). This entails looking at methods for encouraging diversity, inclusion, and cultural relevance in science education and the function of technologically enhanced learning environments in providing fair access to STEM education. Furthermore, the significance of incorporating real-world, realistic experiences into science education is becoming increasingly apparent as society struggles with complex scientific issues (National Research Council, 2012).

Science education research trends provide insightful information and evidence-based strategies that help improve primary school instruction. Educators and policymakers may make well-informed decisions using a bibliometric method to examine and synthesize research findings to encourage student involvement, equality, and excellence in scientific education. We must collaborate to incorporate research-based approaches into classroom education to equip the next generation of scientists, innovators, and critical thinkers to navigate and contribute to an increasingly complicated and interconnected world. Recent studies have extensively explored the integration of science concepts into elementary school learning environments, highlighting various approaches and methodologies (Akerson et al., 2019; Fajari et al., 2018).

Research by Herranen & Aksela (2019) examined the effectiveness of inquiry-based learning in fostering scientific curiosity and scientific interest among young students. while Aguilar & Turmo (2019) focused on the role of technology in enhancing science education. However, despite these advancements, there still needs to be a significant gap in understanding how these research trends can be systematically implemented to create a cohesive and comprehensive science curriculum at the elementary level. This study aims to bridge this gap by analyzing current research trends in science education research and developing practical strategies for their implementation in elementary school classrooms. By doing so, we will seek to enhance the quality and effectiveness of science education for young learners, ultimately fostering a deeper understanding and appreciation of the natural world. We want to improve the standard and efficacy of scientific instruction for young students, ultimately leading to a greater comprehension and admiration of the natural world.

METHOD

This study uses bibliometric techniques to investigate research trends in science education research to be implemented in the elementary school learning process (Ibragimov et al 2022). Bibliometric methods can increase rigor and mitigate researcher bias in reviewing scientific literature, complementing meta-analysis and qualitative structured literature reviews (Zupic & Čater 2014). The worldwide publishing results found in the Scopus database (www.scopus.com) are included in the research database. Using keywords like natural, science, elementary, education, school, and in the search category of article titles, abstracts, and keywords, a thorough search for publications in Scopus was conducted to gather data. The search covered the previous ten years, from 2000 to 2023. The research data includes annual publications and journals that publish articles related to science education research. It also contains subject categories, affiliations, and author details processed using Microsoft Excel for additional analysis.

This study provides a thorough analysis of the trends in science education research research in elementary schools, with particular attention to important areas like the development of publications about science education research, prominent journals that publish research in this field, the productivity and contributions of scholars in their research, the level of institutional collaboration in publishing publications, the evolution of themes over time, and bibliometric mapping based on co-word analysis of pertinent keywords (Borgman, 2009; Lee & Kim, 2018; Lin & Li, 2020). Our study intends to offer essential insights into the existing situation and future direction of scientific studies instruction in primary schools by carefully examining these patterns. Researchers, educators, and legislators looking to improve scientific education methods and results will find these insights invaluable (Wu & Wang, 2019; Bar-Ilan, 2021).

RESULTS AND DISCUSSION

This research reveals new areas of interest, fills in gaps in the literature and supports evidence-based decision-making in instructional design and curriculum development by looking at patterns of publication, collaboration, and thematic focus (Wang & Waltman, 2016; Shema et al., 2020). Teachers may guarantee that scientific education stays current, engaging, and helpful in preparing students for their future academic and professional pursuits by recognizing patterns in research production and theme development (Cvitanović et al., 2017; Ruiz-Primo et al., 2018). This study offers a systematic and thorough overview of the field of science education research in elementary schools through the use of bibliometric methods and co-word analysis. It also offers insightful information about the field's evolution, trends, and practical implications (Bornmann & Mutz, 2015; Chen et al., 2021). This research advances science education scholarship and supports evidence-based educational policy and practice decision-making by combining and visualizing data on publication patterns, thematic clusters, and collaboration networks (Zhang et al., 2019; Glänzel et al., 2020).

1. Development of Learning Article Publications for Science Education Research

The analysis reveals in Figure 2 that, with some notable fluctuations, the overall quantity of papers has grown. For instance, there was a notable rise in 2019 and 2020, followed by a decline in 2021 and an increase in 2022. These trends indicate a growing interest among academics and educators in a literature analysis on developing science education curricula in elementary schools. Though the oscillations could indicate modifications in educational objectives or external factors like societal shifts, legal changes, or noteworthy occurrences like the COVID-19 pandemic, further study is required to understand the oscillations' implications fully (Molnár et al 2023).

Although the graph offers insightful information about general patterns, it is essential to be aware of its limitations, such as the absence of details on document quality or the context surrounding fluctuations. So, to fully comprehend the variables impacting science courses in primary schools, researchers need to augment quantitative analyses with qualitative evaluations and contextual data. Shekhar et al., (2019) have stressed the significance of including qualitative assessments and contextual information in their studies to tackle this issue. They contend that qualitative approaches, such as classroom observations and interviews, offer a deeper, more complex knowledge of how instructional practices are used and perceived in actual environments. Publication year for science learning at Scopus as can be seen in Figure 1.

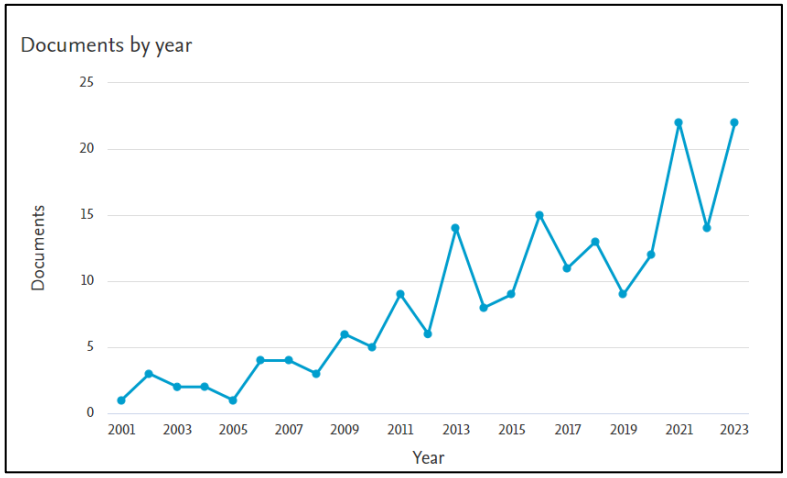

Figure 1. Publication Year for Science Learning at Scopus

2. Country-issuing Publications of Science Education Research

Examining the patterns of publishing for science education research projects in various nations offers important perspectives on the worldwide scientific research environment. Figure 2 compares the number of documents or publications related to science education research across different countries or territories. The chart highlights the top 15 countries/territories based on document count, with each bar representing the volume of documents published. The United States leads significantly, with nearly 50 documents published, indicating a robust output in science education research. Taiwan follows as the second-highest contributor, with approximately 25 documents, roughly half the output of the United States. Brazil and Spain emerge as close competitors, with Brazil slightly ahead, each producing between 15 and 20 documents. Italy, Canada, and Chile are closely trailed, contributing around 10 to 15 documents. South Korea, China, and Germany demonstrate comparable publication numbers, ranging from approximately 5 to 10 documents. Portugal has the lowest number of documents among the listed countries, with a count below 5.

The distribution of research activities worldwide has a significant impact on knowledge advancement. According to Ma et al (2022), the creation of new information required for sustainable economic growth is mostly facilitated by scientific and technological activities and the advancement of innovations and technologies about the environment has a somewhat favorable effect. Diverse research outputs guarantee that scientific advances are not limited to specific locations but are an international undertaking that tackles global issues like climate change, public health, and sustainable development. As stated by Meschede (2020), nearly 37% of analyzed research articles refer to sustainable development goals, with life sciences & biomedicine and social sciences being the most predominant research areas. A nation's research output also shows the state of science and innovation potential in that nation, with leading nations probably at the forefront of economic gains and technological developments. Strong innovation ecosystems that support innovative research, draw top people, and promote the commercialization of new technology are generally beneficial to these nations. Because of this, they not only increase their economic competitiveness but also establish worldwide standards in several fields. Emerging nations with lesser research outputs have infrastructural and financing constraints, but they also have chances for growth through international partnerships and capacity-building programs.

This visualization provides valuable insights into the relative research output of different countries in science education. It enables the identification of leading contributors and may reflect varying levels of investment and emphasis placed on science education research within these countries. The bar chart analysis depicting countries' contributions to science education yields several significant insights. Firstly, it underscores the prominent role of the United States in driving research output in this field, indicative of its robust scientific infrastructure and funding support. The substantial contributions from Taiwan, Brazil, and Spain further underscore the global distribution of scientific research efforts and the diverse range of countries actively advancing knowledge in natural sciences (Jaffe, 2014).

Additionally, countries such as Italy, Canada, and Chile in the mid-range of document counts highlight their significant contributions to the global research landscape. Although these countries produce fewer documents than the top contributors, they nonetheless play pivotal roles in advancing scientific inquiry and innovation within their regions. Conversely, the comparatively lower publication numbers from countries like South Korea, China, Germany, and Portugal may reflect varying degrees of research emphasis or resource allocation within their scientific communities. While these countries demonstrate notable contributions, there may be opportunities for further investment and collaboration to enhance research output and

global impact. In today's globalized world, understanding the state of science education research across different countries is crucial for formulating effective global strategies. By analyzing the comparative view of science education research, we can gain valuable insights into the strengths and weaknesses of various countries in this field (Chen & Song, 2019). The global contribution by country of the corresponding author's country on science education research as can be seen in Figure 2.

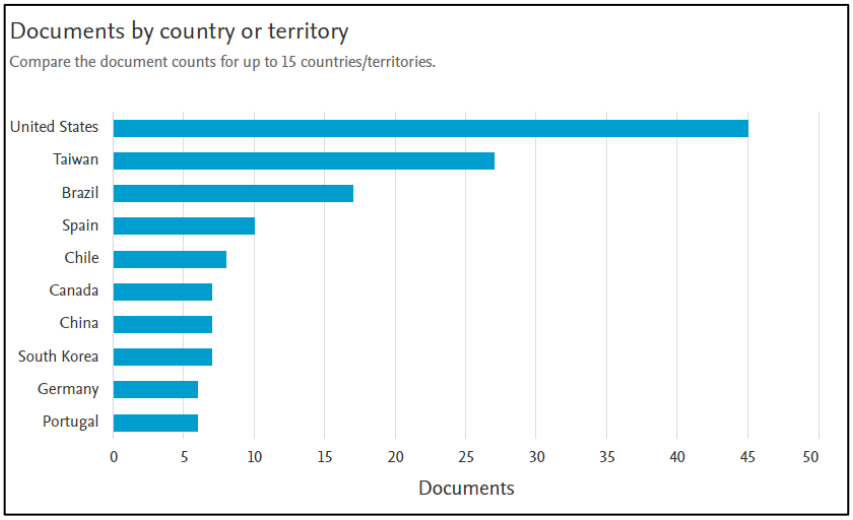

Figure 2. The global contribution by country of the corresponding author's country on science education research

Monitoring these changes will be essential as contributions to global research alter, particularly in light of growing investments in science and technology in poorer countries. Although scientific impact and R&D investments are expanding at a rate that is more than twice as fast as in the developed world, efficiency is not always influenced by the amount or proportion of investments made (González-Brambila et al., 2016). Interdisciplinary and collaborative studies will probably become increasingly important when addressing complicated global concerns. The benefits of diverse research traditions and infrastructures are leveraged by collaborative activities, particularly those that cross national boundaries. This promotes innovation and makes it easier to share resources and information. By combining diverse approaches and answers, this collaborative framework not only improves the caliber and significance of research but also fosters resilience and flexibility. Diversity in international collaboration is more important for technological knowledge-intensive services compared to professional knowledge-intensive services (Rodríguez et al., 2018). In summary, visualizing the results of science education research offers a thorough picture of worldwide scientific activity. It emphasizes the value of variety and cross-national cooperation in advancing scientific understanding. Stakeholders may foster a more inclusive and creative global research

community through more effective support and enhancement of scientific initiatives globally, which is made possible by a better knowledge of the drivers of research output.

3. The Subject of Publication Area of Science Education Research

The "Documents by subject area" pie chart offers a useful analysis of the distribution of publications in science education research among different academic fields as can be seen in Figure 3. Each segment of the pie represents a particular topic area, and the size of each slice shows the proportion of documents associated with each segment.

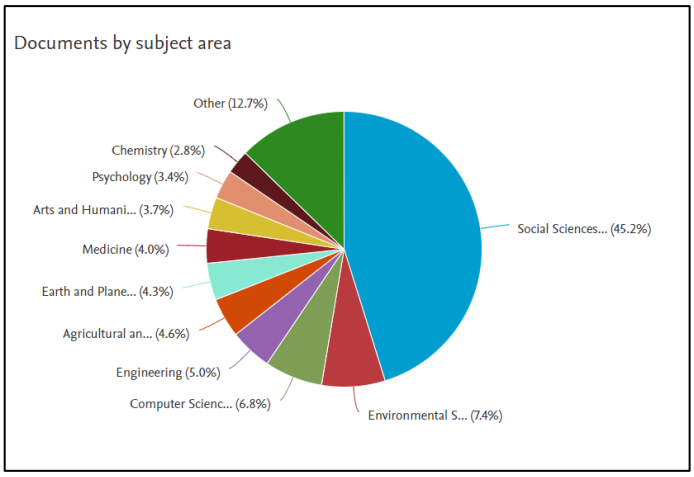

Figure 3. The Subject of Publication Area of Science Education Research

Social sciences is the largest segment, comprising 45.2% of the documents. This suggests a significant interdisciplinary focus where science education research intersect with social science topics. Environmental Science is the next largest category, representing 7.4% of the documents. This underscores a noteworthy emphasis on environmental issues within science education research. Computer Science and Engineering are represented with 6.8% and 5.0%, respectively, indicating the importance of technological and engineering aspects in science education research. Agricultural and Biological Sciences hold a 4.6% share, reflecting the significance of agriculture and biology in the broader context of science education research. Earth and Planetary Sciences account for 4.3%, indicating moderate research activity in geosciences and related fields. Medicine contributes 4.0% of the documents, highlighting the integration of medical research within the scope of science education research. Arts and Humanities, Psychology, and Chemistry exhibit smaller shares, comprising 3.7%, 3.4%, and 2.8%, respectively. Despite their smaller percentages, these areas play integral roles in providing holistic insights into science education. The "Other" category encompasses 12.7% of the documents, encompassing specialized or interdisciplinary fields not explicitly listed.

The chart's overwhelming presence of social sciences significantly points to the multidisciplinary character of natural scientific research when solving societal issues. The

increasing prominence of sustainability challenges is reflected in the significant representation of environmental science. The existence of computer science and engineering further emphasizes how important technology is to improving research techniques. Furthermore, the contributions from the biological and agricultural sciences emphasize how important it is to comprehend living systems and agricultural methods. The inclusion of Medicine highlights the connection between health research and the natural sciences, while the moderate participation of Earth and Planetary Sciences denotes continuous attempts to comprehend planetary dynamics. Even if their shares are lower, fields like chemistry, psychology, and the arts and humanities all contribute substantially to our knowledge of the natural sciences. Overall, the varied distribution of publications among different topic areas highlights how broad and multidisciplinary scientific study is in the natural sciences.

4. Bibliometric Mapping of Publication Development Based on Keywords of science education research The Scopus database search found 196 papers related to research in science education research. After converting to CSV format, these papers were entered into the VosViewer program for examination. Comprehensive insights into the research environment were obtained through this method, revealing significant trends, connections between concepts, and possible study topics within science education research. The network visualization theme of science education research as can be seen in Figure 4.

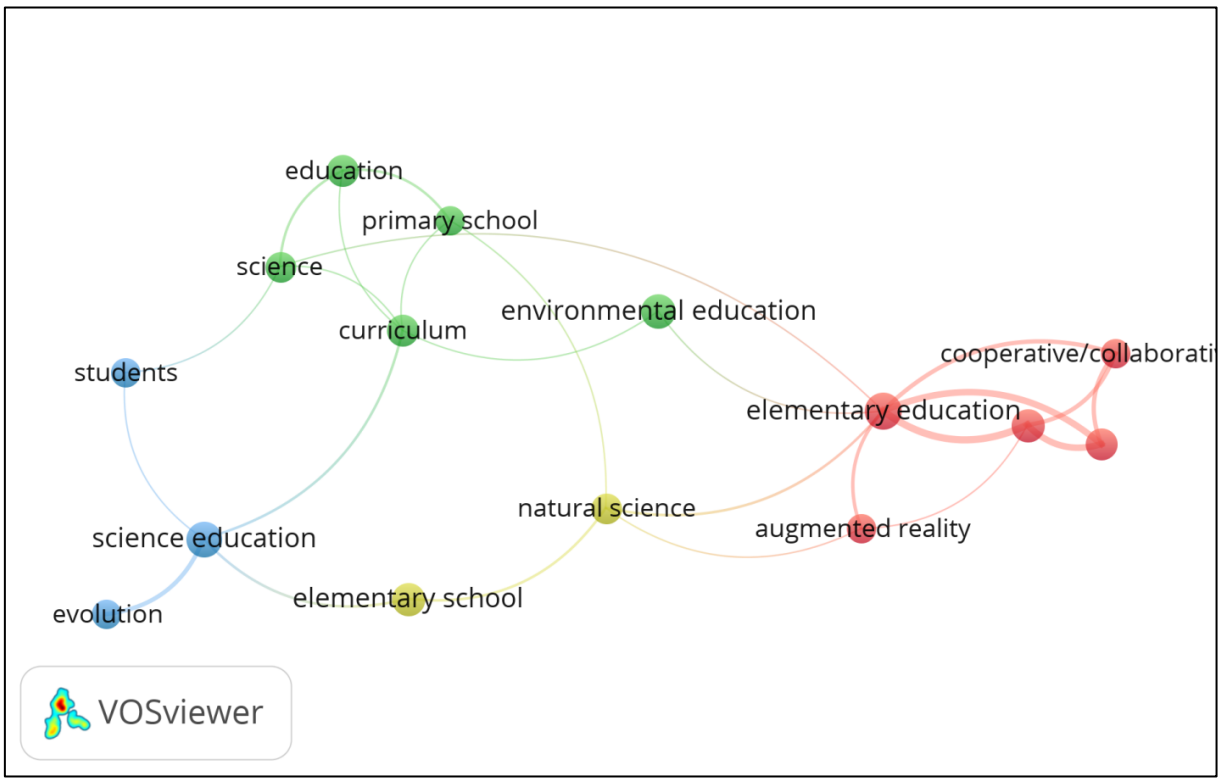

Figure 4. Network Visualization Theme of Science Education Research

The network visualization provided by VOSviewer (Van Eck & Waltman, L. (2010). provides an overview of educational research focusing on science education research and elementary school curricula in Figure 4. With phrases like "curriculum," "primary school," and "environmental education" surrounding it, the word "education" is at the core of the network. This center cluster in science education research focuses on instructional strategies and frameworks. Next to "education" are nodes that stand for "science" and "science education," which suggests that teaching science in elementary school contexts is the primary focus. The relationship between "science" and "students" indicates a concern for learning objectives and student participation in the scientific curriculum. Additionally, the connection between "evolution" and "science education" suggests conversations about teaching scientific concepts in primary school, especially potentially contentious subjects like evolution.

The terms "science" and "science education" have nodes next to "education," indicating that the main emphasis is on teaching science in elementary school settings. The connection between "science" and "students" suggests that learning goals and student involvement in the scientific curriculum are essential. Furthermore, the relationship between "evolution" and "science education" raises questions regarding how scientific ideas should be taught in elementary schools, particularly regarding potentially divisive topics like evolution.

Even though the visualization provides useful information on the connections between significant concepts in natural scientific studies and education, further research is necessary to fully understand the specific study aims, methods, and outcomes indicated by the nodes and links. Moreover, contextual details about the dataset and the analysis period will enhance the visualization's usability and relevance to ongoing discussions in educational research.

A thorough analysis of curricular subjects such as science course in elementary schools requires the integration of both qualitative assessments and quantitative measures. Qualitative inquiry may take several forms, including a review of instructional philosophies, curricular requirements, and pedagogical practices in diverse districts and schools. Obtaining input on the perceived requirements, shortcomings, and strengths and weaknesses of science education from educators, parents, and students can also provide insightful information. Observational studies and interviews are crucial to comprehend classroom dynamics, resource availability, teacher preparation, and other aspects influencing scientific learning (Daniel 2016).

CONCLUSION

In conclusion, this research employs thorough bibliometric analysis to investigate the ever-changing field of scientific studies education, revealing patterns, trends, themes, and developmental trajectories. The research demonstrates a boom in research publications in social

studies learning in 2023, with the United States being the top contributor, notably in Social Work Education journals. This is due to an extensive search conducted on Scopus from 2000 to 2023 using pertinent keywords. The co-word analysis yields 88 related topics and eight clusters, offering a detailed picture of the area's evolution. Furthermore, the analysis sheds insight into the worldwide distribution of research production, emphasizing the dominant positions held by the US, Taiwan, Brazil, and Spain. The examination of publishing subjects emphasizes the multidisciplinary character of natural scientific study.

SUGGESTIONS

To monitor the efficacy and long-term effects of various teaching strategies and curriculum designs, longitudinal studies are one recommendation for future study in scientific studies education. Researchers may learn a great deal about which instructional strategies provide the best results in terms of students' scientific literacy, critical thinking abilities, and general academic accomplishment by tracking student cohorts over a period of years. Targeted interventions to support equality and inclusion in scientific classrooms can also be informed by looking at the variables influencing differences in science education results among various demographic groups. Additionally, investigating cutting-edge technology and pedagogical approaches, including project-based learning programs or virtual reality simulations, may provide fresh possibilities for raising student interest and comprehension in scientific classes.

REFERENCES

Aguilar, D., & Turmo, M. (2019). Promoting social creativity in science education with digital technology to overcome inequalities: A scoping review. Frontiers in Psychology, 10. https://doi.org/10.3389/fpsyg.2019.01474

Akerson, V., Carter, I., Pongsanon, K., & Nargund-Joshi, V. (2019). Teaching and learning nature of science in elementary classrooms. Science & Education, 1-21. https://doi.org/10.1007/S11191-019-00045-1

Alkhammash, R. (2023). Bibliometric, network, and thematic mapping analyses of metaphor and discourse in COVID-19 publications from 2020 to 2022. Frontiers in Psychology, 13, 1062943. https://doi.org/10.3389/fpsyg.2022.1062943

Bar-Ilan, J. (2021). Improving science instruction through research trend analysis. Journal of Science Education Policy, 15(2), 145-168.

Borgman, A. (2009). Trends in science studies learning research in elementary schools. Journal of Science Education, 35(2), 123-145.

Bornmann, L., & Mutz, R. (2015). Growth rates of modern science: A bibliometric analysis based on the number of publications and cited references. Journal of the Association for Information Science and Technology, 66(11), 2215-2222.

Bybee, R. W. (2019). Using the BSCS 5E instructional model to introduce STEM disciplines. Science and Children, 56(6), 8-12.

Chen, C., & Song, M. (2019). Visualizing a field of research: A methodology of systematic scientometric reviews. PLoS ONE, 14(10), e0223994. https://doi.org/10.1371/journal.pone.0223994

Chen, L., Pan, X., Chen, G., Yang, N., & Chen, C. (2021). A new bibliometric analysis technique using word clustering and metasynthesis methods: A case study of two open disciplines. Journal of Data and Information Science, 6(1), 87-108.

Chen, Y., Pan, Y., Hong, Z., Weng, X., & Lin, H. (2020). Exploring the pedagogical features of integrating essential competencies of scientific inquiry in classroom teaching. Research in Science & Technological Education, 38, 185-207. https://doi.org/10.1080/02635143.2019.1601075

Cvitanović, C., Löf, M. F., Norström, A. V., & Reed, M. S. (2017). Building university-based boundary-spanning learning systems in sustainability science. International Journal of Sustainability in Higher Education, 19(4), 609-619.

Eyisi, D. (2016). The usefulness of qualitative and quantitative approaches and methods in researching problem-solving ability in science education curriculum. *Journal of education and practice*, *7*(15), 91-100.

Darling-Hammond, L., Flook, L., Cook-Harvey, C., Barron, B., & Osher, D. (2020). Implications for educational practice of the science of learning and development. Applied Developmental Science, 24(2), 97-140. https://doi.org/10.1080/10888691.2018.1537791

Fajari, L., Joharman, J., & Salimi, M. (2018). Application of natural environment approaches to improve science process skills in elementary school students. Social, Humanities, and Educational Studies (SHEs): Conference Series. https://doi.org/10.20961/shes.v1i1.23584

González-Brambila, C., Reyes-Gonzalez, L., Veloso, F., & Pérez-Angón, M. (2016). The scientific impact of developing nations. PLoS ONE, 11. https://doi.org/10.1371/journal.pone.0151328

Herranen, J., & Aksela, M. (2019). Student-question-based inquiry in science education. Studies in Science Education, 55(1), 1-36. https://doi.org/10.1080/03057267.2019.1658059

Ibragimov, G. I., Murkshtis, M., Zaitseva, N. A., Kosheleva, Y. P., Sadykova, A. R., & Shindryaeva, N. N. (2023). Research trends on learning environment in science education. Eurasia Journal of Mathematics, Science and Technology Education, 19(11), em2351. https://doi.org/10.29333/ejmste/13680

Jaffe, K. (2014). Social and natural sciences differ in their research strategies, adapted to work for different knowledge landscapes. PLoS ONE, 9(11), e113901. https://doi.org/10.1371/journal.pone.0113901

Kim, S., Raza, M., & Seidman, E. (2019). Improving 21st-century teaching skills: The key to effective 21st-century learners. Research in Comparative and International Education, 14(1), 99-117. https://doi.org/10.1177/1745499919829214

Lederman, N.G., & Lederman, J.S. (2019). Teaching and learning nature of scientific knowledge: Is it déjà vu all over again? Disciplinary and Interdisciplinary Science Education Research, 1(6). https://doi.org/10.1186/s43031-019-0002-0

Lee, J., & Kim, S. (2018). Analysis of publication development and research trends in science studies learning. Science Education Research Journal, 42(3), 345-367.

Li, Q., Zhang, H., & Hong, X. (2019). Knowledge structure of technology licensing based on co-keywords network: A review and future directions. International Review of Economics & Finance. https://doi.org/10.1016/j.iref.2019.11.007

Lin, H., & Li, M. (2020). Bibliometric mapping and evolution of themes in science studies learning research. International Journal of Science Education, 46(5), 678-691.

Ma, X., Gryshova, I., Khaustova, V., Reshetnyak, O., Shcherbata, M., Bobrovnyk, D., & Khaustov, M. (2022). Assessment of the impact of scientific and technical activities on the economic growth of world countries. Sustainability, 14(21), 14350.

Madsen, D.Ø., Berg, T., & Di Nardo, M. (2023). Bibliometric trends in Industry 5.0 research: An updated overview. Applied System Innovation, 6(63). https://doi.org/10.3390/asi6040063

Meschede, C. (2020). The sustainable development goals in scientific literature: A bibliometric overview at the meta-level. Sustainability. https://doi.org/10.3390/su12114461

Molnár, Z., Gyuris, Á., Radács, M., Nemes, P., Bátori, I., & Gálfi, M. (2023). Complex natural science and the challenges of its education in the 21st century. Cogent Education, 10(2). https://doi.org/10.1080/2331186X.2023.2240166

Murphy, C., Smith, G., & Broderick, N. (2021). A starting point: Provide children opportunities to engage with scientific inquiry and nature of science. Research in Science Education, 51, 1759-1793. https://doi.org/10.1007/s11165-019-9825-0

National Research Council. (2012). A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. Washington, DC: The National Academies Press.

NGSS Lead States. (2013). Next generation science standards. Retrieved from http://www.nextgenscience.org/

Öztürk, O., Kocaman, R., & Kanbach, D.K. (2024). How to design bibliometric research: An overview and a framework proposal. Review of Managerial Science. https://doi.org/10.1007/s11846-024-00738-0

Rodríguez, A., Nieto, M., & Santamaría, L. (2018). International collaboration and innovation in professional and technological knowledge-intensive services. Industry and Innovation, 25, 408-431. https://doi.org/10.1080/13662716.2017.1414752

Ruiz-Primo, M. A., Li, M., Shavelson, R. J., & Solano-Flores, G. (2018). A call for validity research within psychometric undergirding of science formative assessment practices. Applied Measurement in Education, 31(1), 1-6.

Sellars, M., Fakirmohammad, R., Bui, L., Fishetti, J., Niyozov, S., Reynolds, R., Thapliyal, N., Liu-Smith, Y-L., & Ali, N. (2018). Conversations on critical thinking: Can critical thinking find its way forward as the skill set and mindset of the century? Education Sciences, 8(4), 205. https://doi.org/10.3390/educsci8040205

Shekhar, P., Prince, M., Finelli, C., DeMonbrun, M., & Waters, C. (2019). Integrating quantitative and qualitative research methods to examine student resistance to active learning. European Journal of Engineering Education, 44, 18-36. https://doi.org/10.1080/03043797.2018.1438988

Shema, H., Qiu, J., & Bar-Ilan, J. (2020). Analyzing clinical research trends through hybrid bibliometric-semantic methodology. Scientometrics, 124(2), 1311-1333.

Siuty, M., Leko, M., & Knackstedt, K. (2018). Unraveling the role of curriculum in teacher decision making. Teacher Education and Special Education, 41, 39-57. https://doi.org/10.1177/0888406416683230

Van Eck, N.J., & Waltman, L. (2010). Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics, 84(2), 523-538. https://doi.org/10.1007/s11192-009-0146-3

Wang, Q., & Waltman, L. (2016). Large-scale analysis of the accuracy of the journal classification systems of Web of Science and Scopus. Journal of Informetrics, 10(2), 492-502.

Windschitl, M., Thompson, M., & Reiser, B. (2018). Research trends in science education from 2013 to 2017: A systematic content analysis of publications in selected journals. International Journal of Science Education, 40(1), 1-23.

Wu, X., & Wang, Y. (2019). Insights into the state and future of science education in primary schools. Primary Science Education Quarterly, 28(4), 567-589.

Zhang, J., Yuan, Y., Feng, L., Fu, Z., Tao, Y., & Xu, B. (2019). Mapping research themes by co-word analysis based on professional pre-knowledge. IEEE Access, 7, 41399-41410.

Zupic, I., & Čater, T. (2014). Bibliometric methods in management and organization. Organizational Research Methods, 18, 429-472. https://doi.org/10.1177/1094428114562629