# Global Trend of AI-Augmented STEM Learning Research in The Last Ten Years

**Faiq Makhdum Noor[1], Dody Rahayu Prasetyo[2], Iseu Laelasari[3], Dwi Anjar Martitik[4], Hanik Malichatin[5], Ulya Fawaida[6]**

Tadris IPA Study Program, State Islamic University of Sunan Kudus, Kudus, Indonesia[1-6]
Jl. Conge Ngembalrejo Bae Kudus, Jawa Tengah, PO BOX 51
faiq@uinsuku.ac.id

**ABSTRACT**

AI-Augmented STEM Learning is a way of teaching Science, Technology, Engineering, and Mathematics (STEM) that uses Artificial Intelligence (AI) to enhance, broaden, and personalize the learning experience for students. This study aims to analyze the trends in research on AI-Augmented STEM Learning, the types of documents, the most productive researchers, the countries and affiliations that contribute the most, and a visual map of bibliometric data using the VOSviewer program. The results of this bibliometric study show that the trend of research in AI-Augmented STEM Learning has been growing each year from 2017 to 2026. The most commonly available type of document is articles, and the majority of these documents come in the form of journals. The country that produces the most documents on AI-Augmented STEM Learning is the United States, while Indonesia ranks ninth in producing the most documents. The affiliate that produced the most documents is the Puls Med Association, with a total of 6 documents. On the other hand, the affiliate from Indonesia is Malang State University, which has 2 documents. The most productive writer is Octavian Munteanu, who has 5 documents. He is from the Department of Anatomy at the "Carol Davila" University of Medicine and Pharmacy in Bucharest, Romania. There are four clusters based on the VOSviewer software visualization that focus on keywords: generative artificial intelligence, innovation, perspective, and teacher. Meanwhile, opportunities and potential for future research related to STEM Learning using AI that are currently still underexplored include topics on STEM education using AI, student engagement, and systematic literature reviews.
**Keywords**: STEM Learning, Artificial Inteligence, Bibliometric

## INTRODUCTION

Learning Science in the 21st century faces many challenges that are becoming more complicated as technology advances and the needs for global skills change. Science learning should no longer focus only on understanding concepts and memorizing facts. Instead, it should help students develop skills like critical thinking, problem-solving, creativity,

collaboration, and digital literacy (Agarwal & Bain, 2024; Rosario, 2025). However, various studies show that the science learning process in many schools is still mostly focused on a teacher-centered approach. This leads to students being less actively involved in building their own knowledge. As a result, students' ability to connect science concepts with real-life problems in their surroundings is still quite low (Saija et al., 2022). This situation presents a significant challenge in preparing a generation that can adjust to the rapid changes in science and technology (Leon et al., 2025).

Moreover, the growth of digital technology, especially Artificial Intelligence (AI), has changed how people gather, process, and use information. On the other hand, the easy access to information through digital technology is often not matched by a sufficient ability to think scientifically and have good science literacy (Chang et al., 2023; Miller, 2022). Various studies show that students tend to rely more on finding quick answers instead of truly understanding concepts in depth. As a result, the learning process in science is at risk of losing elements like exploration, curiosity, and critical thinking skills (*Teaching STEM in 2025*, 2025). This challenge requires innovative teaching methods that can meaningfully incorporate technology while still keeping the core of science learning as a process of investigation and scientific discovery (Lee & Zhai, 2024; Saija et al., 2022; Sukmawati & Wahjusaputri, 2024; Zhai, 2023).

In Indonesia, various reports and research findings indicate that the quality of science education still faces several challenges. These include students' low science literacy skills, limited laboratory facilities, a lack of technology integration in teaching, and the not-yet-optimal use of project-based learning and problem-solving approaches (Anggreni et al., 2025; Darmayanti & Pratiwi, 2025; Jamaah et al., 2024). In many schools, science learning still focuses on passing tests, which means that the teaching activities tend to emphasize understanding concepts in theory rather than applying those concepts in real life (Saija et al., 2022; Szarka & Borovicza, 2023). This situation leads to students having fewer chances to develop higher-order thinking skills (HOTS), which are very important for facing the challenges of the Fourth Industrial Revolution and Society 5.0.

One way that is seen as able to address various problems is by using STEM-based learning, which stands for Science, Technology, Engineering, and Mathematics. The STEM approach allows students to learn science concepts in an integrated way through activities like investigation, engineering design, experiments, and solving real-world problems (Xu & Ouyang, 2022a). Through STEM learning, students not only grasp scientific concepts but also learn to use that knowledge to create solutions for real-world problems. Thus, STEM is an important way to build 21st-century skills like creativity, teamwork, communication, and critical thinking that are needed in both life and future job settings (Lafifa et al., 2023).

The growth of Artificial Intelligence (AI) creates new opportunities to enhance the use of STEM in education (Ansiska, 2025). AI can offer

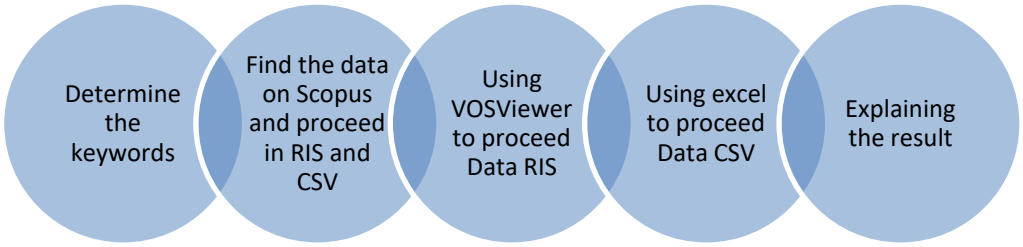
learning that adapts to each student, customizing materials based on their needs. It can analyze learning data in real-time, provide automatic feedback, and create virtual simulations and labs that help explore complex science concepts. The use of AI in STEM education can create a learning experience that is more interactive, effective, and focused on the students (Mai et al., 2025; Xu & Ouyang, 2022b). Moreover, the growth of Generative AI allows students to get help in exploring ideas, creating models, visualizing concepts, and solving problems in a more thorough way (Adari et al., 2025).

Even so, the study of AI-Augmented STEM Learning is still growing and hasn't fully shown a clear direction for research yet. This is especially true when it comes to research trends, study focuses, methodological approaches, and chances for developing learning innovations in different educational settings. Most research still mainly concentrates on the general use of AI technology, while studies that specifically combine the idea of AI-Augmented Learning with STEM education are still quite limited. Therefore, research that looks into the trends of AI-Augmented STEM Learning is important. It helps us understand the latest developments in research, identify research gaps, and uncover new opportunities that could lead to advancements in AI-based STEM learning and innovations in the future. In addition, such studies can provide valuable guidance for educators, researchers, and policymakers in designing more effective, adaptive, and technology-integrated STEM learning environments that are aligned with the demands of 21st-century education.

## METHOD

This study is a descriptive research that uses bibliometric analysis (Noor, 2024; Noor et al., 2022; Yanuarti & Suprapto, 2021). The goal of bibliometric research is to examine the growth of published scientific articles and their impact on knowledge. This research uses the Scopus database. The Scopus database on AI-Augmented STEM Learning research was accessed on May 30, 2026. The research procedure can be seen in Figure 1.

Figure 1:
Research Steps of Bibliometric Research



Scopus metadata-based research identified 324 documents from the last ten years, from 2017 to 2026. The database was downloaded in RIS and CSV formats. This research was filtered using an advanced search with the keyword AI-Augmented STEM Learning. The RIS metadata was analyzed and processed using VOSViewer software. The VOSviewer software permits the creation of maps based on network data, which can be viewed and studied (van Eck & Waltman, 2019). Meanwhile, metadata in CSV format is analyzed and processed using Microsoft Excel. Search strategy using: AI-Augmented STEM Learning AND PUBYEAR > 2016 AND PUBYEAR < 2025.

## FINDINGS AND DISCUSSION

### *Bibliometric Analysis of AI-Augmented STEM Learning Research*

The distribution of AI-Augmented STEM Learning publications has shown a continuous increase from 2017 to 2026. The growing adoption of AI in STEM education aligns with current technological advancements, making research on this topic increasingly relevant and important. The annual growth in the number of publications indicates that the integration of AI into STEM learning has attracted significant attention from researchers across various educational disciplines. This trend also suggests a growing need to develop more innovative and adaptive learning models that effectively leverage AI technologies to enhance the quality of STEM education. The annual distribution of publications is presented in Figure 2.

Figure 2:
Distribution of AI-Augmented STEM Learning Research Trend Documents

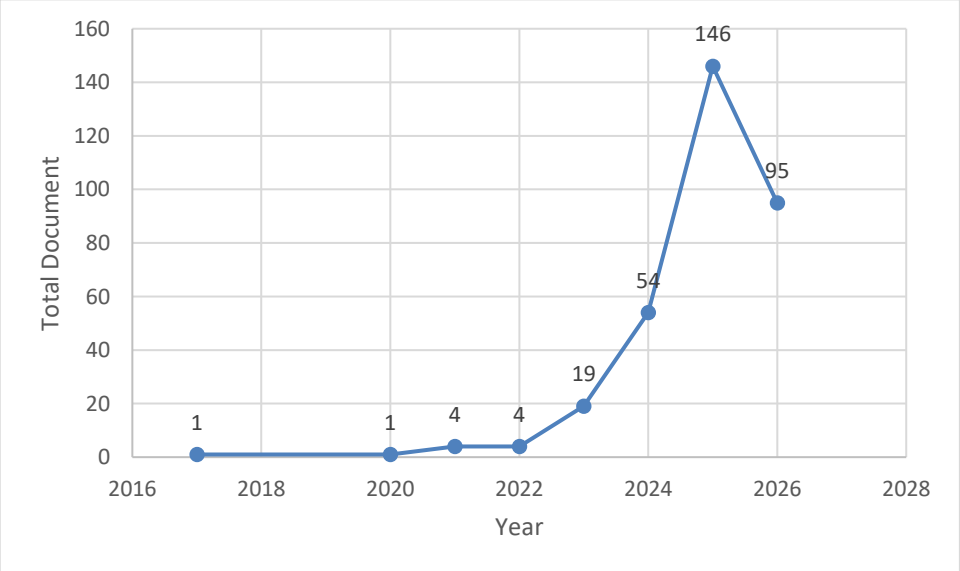



Figure 2 shows that research on AI-Augmented STEM Learning has experienced significant growth in recent years. During the period from 2017 to 2020, the number of publications remained very limited, with only one document published in 2017 and one in 2020. This indicates that the application of artificial intelligence in STEM education had not yet attracted

substantial attention within educational research during that period. From 2021 to 2023, the number of publications increased gradually. In both 2021 and 2022, four documents were published, followed by a notable increase to 19 documents in 2023. This upward trend reflects the growing interest among researchers in integrating AI technologies into STEM learning processes.

The most notable increase occurred in 2024 and 2025. The number of publications reached 54 documents in 2024 and increased sharply to 146 documents in 2025. This substantial growth indicates that AI-Augmented STEM Learning has become an increasingly prominent research topic, particularly with the advancement of generative artificial intelligence technologies, such as ChatGPT, which are being more widely adopted in educational contexts. According to Kasneci et al. (2023), the emergence of generative AI technologies offers significant opportunities to support STEM learning by providing rapid feedback, assisting with problem-solving, and enhancing students' creativity. Meanwhile, the number of publications declined to 95 documents in 2026. However, this decrease is likely attributable to the ongoing indexing process for publications released in 2026, meaning that the available data may not yet be fully comprehensive. Overall, the trend illustrated in the figure indicates that research on AI-Augmented STEM Learning continues to expand and holds considerable potential for further investigation as an innovative approach to science and technology education (Olatunbosun Bartholomew Joseph & Nwankwo Charles Uzondu, 2024).

Figure 3:
Network Visualization of AI-Augmented STEM Learning by VOSViewer

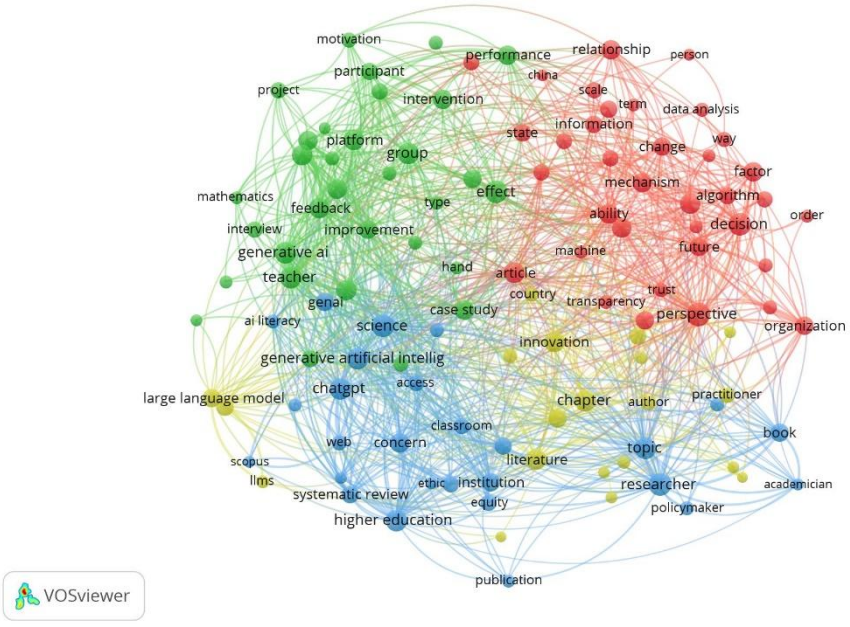


Figure 3 presents a network visualization of the relationships among terms associated with AI-Augmented STEM Learning. Based on the color distribution shown in Figure 3, four clusters can be identified, represented by the terms *generative artificial intelligence* (blue), *teacher* (green), *perspective* (red), and *innovation* (yellow). The terms appearing in the network visualization represent keywords that frequently occur in publications related to AI-Augmented STEM Learning. Generative artificial intelligence, teacher, perspective, and innovation are among the key terms most closely associated with AI-Augmented STEM Learning research. Generative AI, as a form of innovation in artificial intelligence, is now a key part of the technology transformation. As time has passed, generative AI has made a lot of progress, creating new opportunities and having a big impact in many different areas (Bau et al., 2024).

The network visualization also highlights potential directions for future research. Several keywords, including *AI-supported STEM education*, *student engagement*, and *systematic literature review*, exhibit relatively few connections with other keywords in the network. This finding suggests that these topics remain underexplored within the existing literature and offer opportunities for further investigation. Future studies may examine these areas in greater depth by integrating related concepts or by developing innovative learning approaches that strengthen the relationships among research themes in AI-Augmented STEM Learning (Mai et al., 2025; Xu & Ouyang, 2022b).

Figure 4:
Potential Keywords for Future Research and Innovation (STEM Education, Student Engagement, dan Systematic Literature Review)

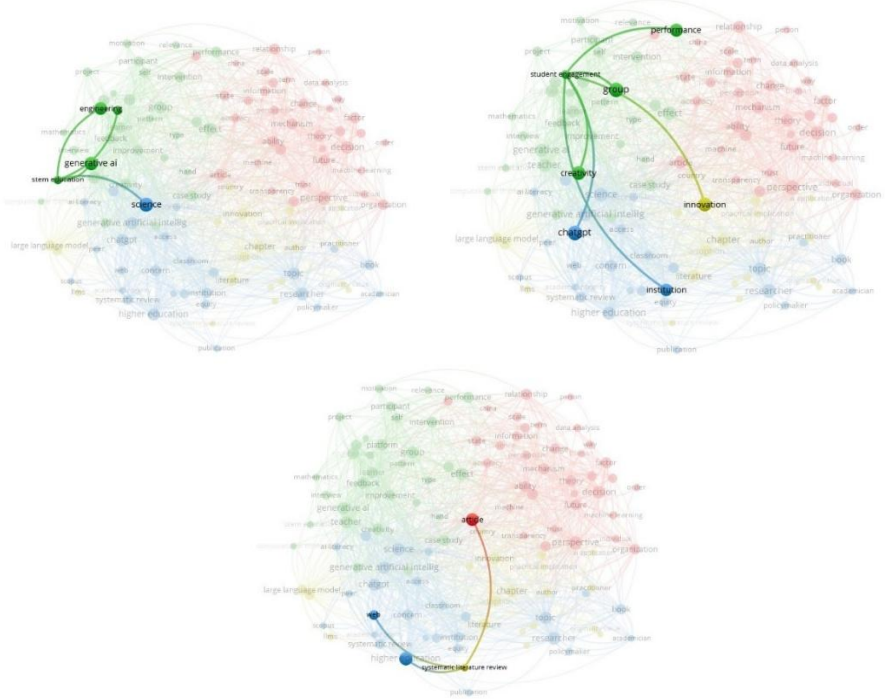


Figure 4 highlights several keywords that have received relatively limited attention in the existing literature, including *STEM education*, *student engagement*, and *systematic literature review*. Among these, *STEM education* is connected to only a few keywords, such as *generative AI*, *science*, and *engineering*, with relatively low occurrence frequencies, as indicated by the smaller node size compared to other keywords in the network. This suggests that the intersection of *STEM education* and *generative AI* remains an emerging area of research and may offer opportunities for identifying novel research contributions in future studies. The use of AI in education is being explored through the integration of AI technology in STEM learning at high schools. This approach focuses on personalization, challenges, and implications. Despite its potential, STEM education still faces several difficulties, including gaps in access and limitations of traditional methods. Therefore, it is important to study how AI technology can be used effectively in STEM education in schools. This is especially necessary to meet the personalized learning needs and to develop strategies and solutions to address the challenges in education (Uban Subandi & Supardi Us, 2024).

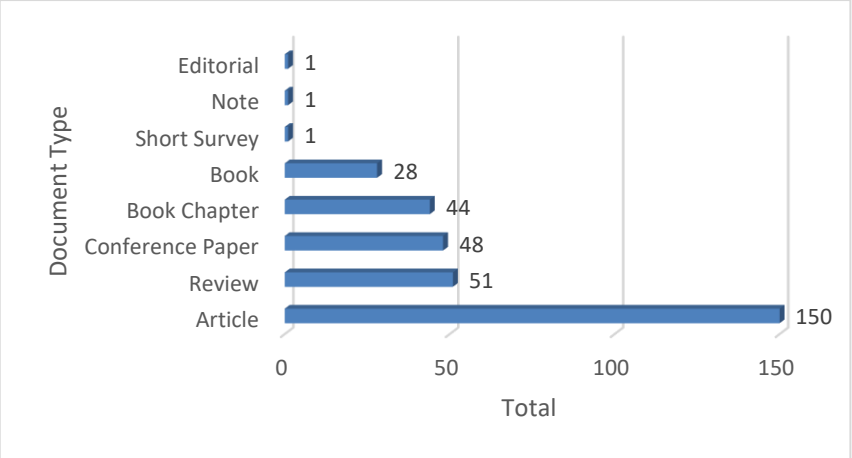
The second keyword is *student engagement*. This keyword is connected to only a limited number of terms, including *performance*, *group*, *creativity*, *ChatGPT*, *institution*, and *innovation*. The occurrence frequency of *student engagement* is also relatively low, as indicated by its smaller node size compared to other keywords in the network. According Muhammad Yatim (2024), STEM education has the potential to enhance student engagement. In addition, the STEM approach can foster students' critical thinking, creativity, collaboration, and problem-solving skills (Prasetyo et al., 2025). Nevertheless, based on the VOSviewer visualization, studies examining student engagement in AI-supported STEM learning remain limited. This is reflected in the relatively low occurrence and connectivity of the *student engagement* keyword within the network.

The third keyword is *systematic literature review*. This keyword is represented by a very small node and is connected to only three other terms, namely *article*, *higher education*, and *web*. This finding indicates that the use of *systematic literature review* as a research approach in studies on AI-Augmented STEM Learning remains limited. Therefore, future research may benefit from employing this method to provide a more comprehensive synthesis of the existing literature and to identify emerging trends and research gaps in the field. Systematic Literature Review (SLR) is a methodical approach to gathering, critically assessing, integrating, and summarizing findings from research related to a specific topic that you want to study (Lusianti et al., 2024).

### *AI-Augmented STEM Learning Research by Document Type and Source Type*

The majority of publications were published as journal articles. This finding indicates that researchers predominantly disseminate their work through academic journals rather than book publishers. Review articles and conference papers represent the second and third most common document types, respectively, followed by book chapters, books, and other publication formats.

Figure 5:
AI-Augmented STEM Learning Research by Document Type

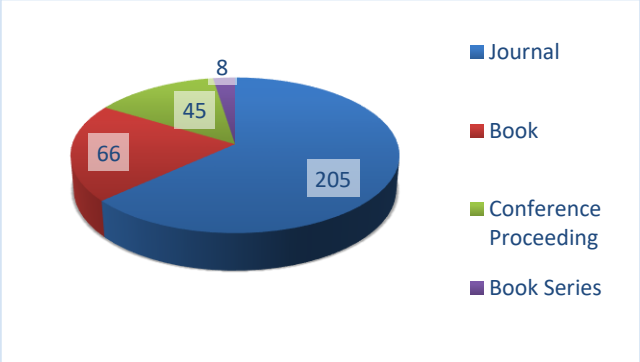



Based on Figure 5, the most dominant document type in AI-Augmented STEM Learning research is articles, accounting for 150 documents. This number is substantially higher than that of other document types, indicating that academic journals serve as the primary outlet for disseminating research on AI-Augmented STEM Learning. The next most common document type is review articles, with 51 documents, followed by conference papers with 48 documents and book chapters with 44 documents. Meanwhile, books account for 28 documents, suggesting that this topic is also increasingly being addressed through books and more comprehensive academic references.

In contrast, several document types are represented by only a small number of publications, namely *short survey*, *note*, and *editorial*, each accounting for a single document. This distribution indicates that research on AI-Augmented STEM Learning is primarily disseminated through publications reporting empirical findings and comprehensive literature reviews rather than through brief communications or opinion-based publications. The predominance of journal articles further suggests that AI-Augmented STEM Learning has developed into a well-established research area that has attracted considerable attention from the academic community, resulting in a substantial body of scholarly work published in academic journals (Tsakeni et al., 2025).

With respect to publication source types, journals constitute the predominant source of publications, followed by books, conference proceedings, and book series.

Figure 6:
AI-Augmented STEM Learning Research by Source Type




Based on Figure 6, journals constitute the dominant publication source for research on AI-Augmented STEM Learning, accounting for 205 documents or approximately 63.9% of the total publications. This dominance indicates that research findings in this field are primarily disseminated through scholarly journal articles. The high proportion of journal publications also suggests that AI-Augmented STEM Learning has evolved into a well-established area of research that has attracted considerable attention from the academic community.

In addition to journals, books represent another important publication source, accounting for 66 documents, followed by conference proceedings with 45 documents. The presence of publications in book format suggests ongoing efforts to provide more comprehensive coverage of AI-Augmented STEM Learning, while conference proceedings reflect emerging research trends and recent developments being discussed within the academic community. In contrast, book series constitute the least common publication source, with only 8 documents. Overall, this distribution indicates that the dissemination of research on AI-Augmented STEM Learning remains heavily concentrated in scholarly journals, although other publication sources also contribute to the development and expansion of the field (Almarashdi et al., 2026).

### *AI-Augmented STEM Learning Research by Country*

The distribution of publications by country is presented in Figures 7 and 8.

Figure 7:
Countries' Contribution in AI-Augmented STEM Learning Research

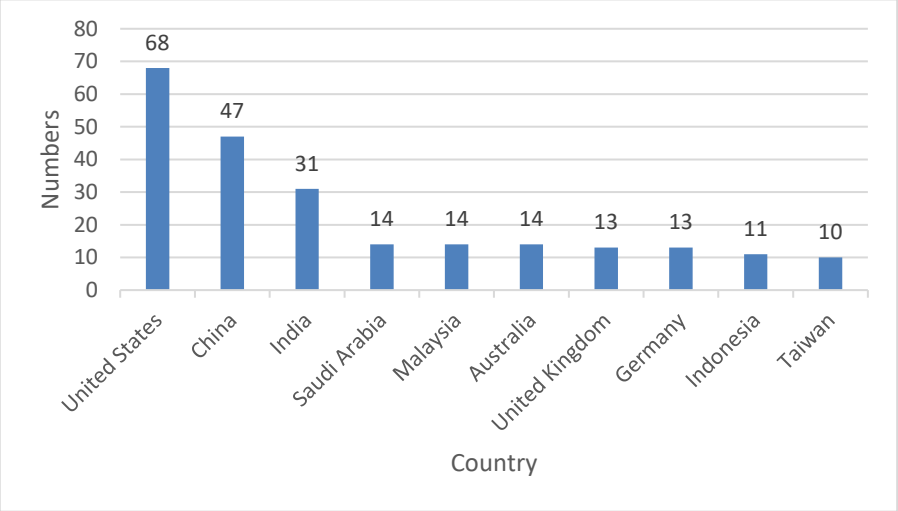
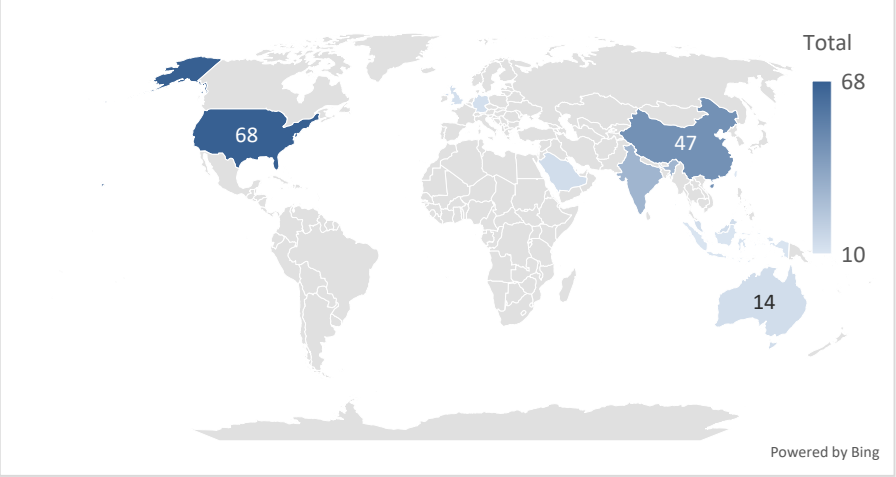



Figure 8:
Visualization of Countries' Contribution in AI-Augmented STEM Learning Research




Figures 7 and 8 illustrate the contributions of different countries to AI-Augmented STEM Learning research based on the number of publications produced. Figure 7 presents the data in the form of a bar chart, whereas Figure 8 displays the distribution of these contributions on a world map. Together, these visualizations provide a consistent overview of the geographical distribution of AI-Augmented STEM Learning research across countries.

Based on Figure 7, the United States is the leading contributor to AI-Augmented STEM Learning research, with 68 publications, followed by China with 47 publications and India with 31 publications. Saudi Arabia, Malaysia, and Australia each contributed 14 publications, while the United Kingdom and Germany produced 13 publications each. Indonesia ranked ninth with 11 publications, followed by Taiwan with 10 publications. These findings indicate that research on AI-Augmented STEM Learning is concentrated in countries with strong research capacity and technological development.

These findings are further supported by Figure 8, which illustrates the geographical distribution of country contributions on a world map. Darker shades indicate a higher number of publications. The United States appears as the darkest region, reflecting its leading contribution to research in this field. China and India also demonstrate substantial contributions within Asia, while Australia emerges as one of the most active contributors in the Oceania region. This geographical visualization suggests that AI-Augmented STEM Learning research is primarily concentrated in North America and Asia.

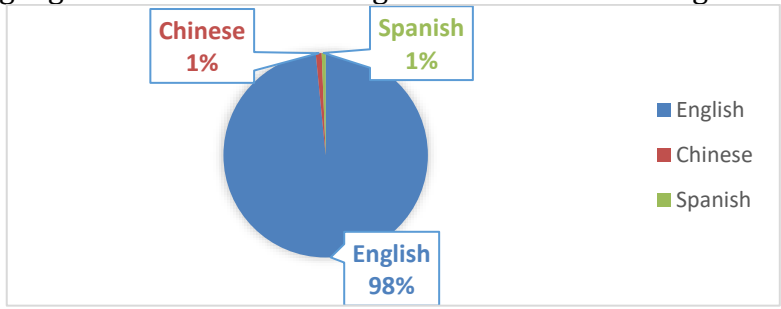
In addition to highlighting the dominance of developed countries, both figures indicate the growing involvement of developing countries in AI-Augmented STEM Learning research. The presence of countries such as India, Saudi Arabia, Malaysia, and Indonesia suggests that the integration of artificial intelligence into STEM education has become a topic of global interest (Kavak, 2023). This trend reflects the growing recognition of the importance of leveraging AI technologies to enhance learning quality, foster 21st-century skills, and prepare students to meet the challenges of the digital era (Irfan et al., 2025).

Overall, Figures 7 and 8 demonstrate that AI-Augmented STEM Learning research is geographically widespread, although it remains dominated by a number of countries with more advanced research and technological ecosystems. This situation also presents opportunities for other countries to strengthen international collaboration and expand their contributions to the advancement of AI-Augmented STEM Learning research in the future.

### *AI-Augmented STEM Learning Research by Language Distribution*

Based on the language distribution of AI-Augmented STEM Learning publications, English is the predominant language, accounting for 317 publications (98%). Chinese is represented by 3 publications (1%), while Spanish accounts for 2 publications (1%).

Figure 9:
Language Distribution in AI-Augmented STEM Learning Research




These findings indicate that English is the dominant language for the dissemination of AI-Augmented STEM Learning research at the global level. This dominance reflects the role of English as the primary language of international scholarly communication. The results also suggest that researchers tend to publish in English to enhance the visibility and reach of their work. In contrast, the relatively small proportion of publications in Chinese and Spanish indicates that research contributions in languages other than English remain limited.

### *AI-Augmented STEM Learning Research by Top Affiliations*

Figure 10 presents the top ten institutional affiliations contributing to AI-Augmented STEM Learning research. Among these institutions, Indonesia is represented by Universitas Negeri Malang, with a total of 2 publications.

Figure 10:
Number of Publications by Top Institutional Affiliations

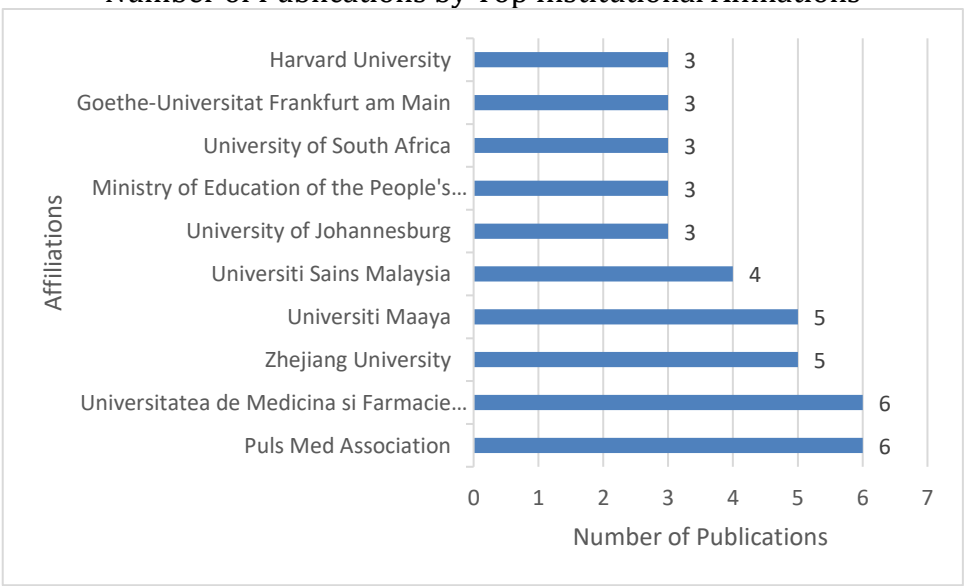


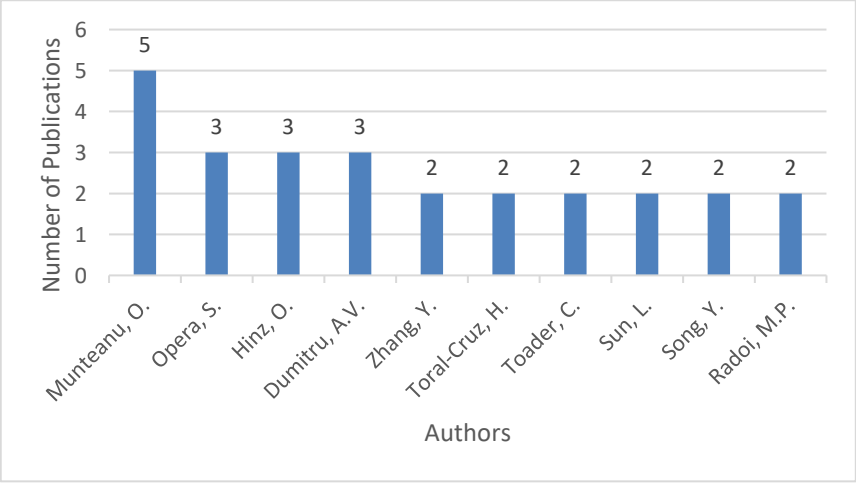
Figure 10 presents the number of publications by the institutional affiliations contributing most actively to AI-Augmented STEM Learning research. The affiliations with the highest number of publications are Pus Med Association and Universitatea de Medicina si Farmacie, each contributing 6 publications. They are followed by Zhejiang University and Universiti Malaya with 5 publications each, and Universiti Sains Malaysia with 4 publications. Meanwhile, the University of Johannesburg, the Ministry of Education of the People's Republic of China, the University of South Africa, Goethe-Universität Frankfurt am Main, and Harvard University each contributed 3 publications.

These findings indicate that research contributions originate from a diverse range of institutions across different countries, reflecting the multidisciplinary and collaborative nature of AI-Augmented STEM Learning research. Furthermore, the differences in publication counts among the top affiliations are relatively small, suggesting a fairly balanced distribution of research output across leading institutions. This pattern indicates that the development of AI-Augmented STEM Learning research is not concentrated within a single institution but is supported by the contributions of various universities and educational organizations worldwide.

### *AI-Augmented STEM Learning Research by Top Prolific Authors*

Figure 11 presents the authors with the highest number of publications on AI-Augmented STEM Learning.

Figure 11:
Number of Publications by Prolific Authors




The most prolific author is Munteanu, C., with a total of 5 publications. Munteanu is affiliated with the Department of Anatomy at the “Carol Davila” University of Medicine and Pharmacy in Bucharest, Romania. This author is followed by Opera, S., Hinz, O., and Dumitru, A.V., each of whom has contributed 3 publications. Meanwhile, Zhang, Y., Toral-Cruz, H., Taoder, C., Sun, Y., Song, Y., and Radoli, M.P. have each published 2 documents.

These findings indicate that publication productivity in AI-Augmented STEM Learning research is distributed across several authors, with no single researcher demonstrating a markedly dominant contribution. Although Munteanu, C. ranks first in terms of publication output, the difference in publication count compared with other leading authors is relatively small. This pattern suggests that the development of research in this field is supported by the contributions of multiple active researchers. Furthermore, the relatively balanced distribution of publication productivity reflects the broad engagement of the academic community in exploring and advancing the application of artificial intelligence in STEM education. The findings also highlight that progress in AI-Augmented STEM Learning research is driven by the collective contributions of researchers from diverse institutional and disciplinary backgrounds.

## CONCLUSION

Bibliometric analysis of AI-Augmented STEM Learning publications from 2017 to 2026 indicates a substantial increase in research output over the past decade, reflecting growing scholarly interest in the integration of artificial intelligence within STEM education. The network visualization generated using VOSviewer identified four major clusters centered on *generative artificial intelligence*, *teacher*, *perspective*, and *innovation*, highlighting the main research themes in the field.

In terms of document type, journal articles were the most prevalent publication format, accounting for 150 documents, followed by review articles (51 documents) and conference papers (48 documents). Regarding source type, journals constituted the dominant publication source with 205 documents, followed by books (66 documents) and conference proceedings (45 documents). The United States emerged as the leading contributor with 68 publications, followed by China (47 publications) and India (31 publications), while Indonesia ranked ninth with 11 publications. English was the predominant publication language, accounting for 317 documents, whereas Chinese and Spanish contributed 3 and 2 documents, respectively.

At the institutional level, Pus Med Association was the most productive affiliation with 6 publications. Indonesia was represented by Universitas Negeri Malang, which contributed 2 publications. Among individual researchers, Octavian Munteanu was identified as the most prolific author with 5 publications and is affiliated with the Department of Anatomy at the “Carol Davila” University of Medicine and Pharmacy in Bucharest, Romania.

The analysis also revealed several underexplored research areas that present opportunities for future investigation, particularly AI-supported STEM education, student engagement, and systematic literature reviews. These topics offer promising directions for advancing knowledge and expanding the research landscape of AI-Augmented STEM Learning.

## REFERENCES

Adari, M. D., Kencana, M., & Fajrina, S. (2025). Antara Bantuan dan Ketergantungan: Literatur Review Pengaruh AI terhadap Kognisi Peserta Didik. *AEJ (Advances in Education Journal)*, *2*(3), 842–852.

Agarwal, P. K., & Bain, P. M. (2024). *Powerful Teaching: Unleash the Science of Learning*. John Wiley & Sons.

Almarashdi, H. S., Khurma, O. A., AlArabi, K., Abulibdeh, E., & Yousef, J. (2026). AI-Enhanced STEM Education: A Bibliometric Study of Research Trends toward Achieving Sustainable Development Goals. *European Journal of STEM Education*, *11*(1). https://eric.ed.gov/?id=EJ1504677

Anggreni, Y., Abdullah, G., Husain, F. A., Kalui, S. N. S., Khairunnisa, S. K., Haleda, H., & Baraka, F. H. (2025). Analisis Problematika Proes Pembelajaran IPA di SD. *KNOWLEDGE : Jurnal Inovasi Hasil Penelitian dan Pengembangan*, *5*(2).

Ansiska, P. (2025). Meningkatkan Pembelajaran STEM dengan AI: Tinjauan Literatur tentang Alat dan Metode Terbaru. *Hatunuku Jurnal Pendidikan IPS*, *1*(1), 39–51. https://doi.org/10.62710/yyxjw550

Bau, R. T. R. L., Istiono, W., Hermila A., H. A., Sari, C. R., Mailangkay, A. B. L., Elisawati, E., Pomalingo, S., & Azmi, M. (2024). *Generative AI* (Vol. 1). Get Press Indonesia.

Chang, C.-Y., Kuo, H.-C., & Du, Z. (2023). The role of digital literacy in augmented, virtual, and mixed reality in popular science education: A review study and an educational framework development. *Virtual Reality*, *27*(3), 2461–2479. https://doi.org/10.1007/s10055-023-00817-9

Darmayanti, N. W. S., & Pratiwi, N. P. D. P. (2025). Mengungkap Faktor Penyebab Rendahnya Pemahaman Konsep IPA pada Siswa dalam Implementasi Kurikulum Merdeka: Studi Kasus di SDN 1 Sumita. *Eduproxima: Jurnal Ilmiah Pendidikan IPA*, *7*(4), 2618–2632.

Jamaah, J., Arnyana, I. B. P., & Suastra, I. W. (2024). Content Analysis: Problematika Pembelajaran Ilmu Pengetahuan Alam (IPA) di Sekolah Dasar Berbasis Kearifan lokal. *JagoMIPA: Jurnal Pendidikan Matematika dan IPA*, *4*(4), 868–874. https://doi.org/10.53299/jagomipa.v4i4.1124

Kasneci, E., Sessler, K., Küchemann, S., Bannert, M., Dementieva, D., Fischer, F., Gasser, U., Groh, G., Günnemann, S., Hüllermeier, E., Krusche, S., Kutyniok, G., Michaeli, T., Nerdel, C., Pfeffer, J., Poquet, O., Sailer, M., Schmidt, A., Seidel, T., … Kasneci, G. (2023). ChatGPT for good? On opportunities and challenges of large language models for education.

*Learning and Individual Differences*, *103*, 102274. https://doi.org/10.1016/j.lindif.2023.102274

Kavak, Ş. (2023). The Evolution and Global Significance of STEM Education in The 21st Century. *The Journal of International Scientific Researches*, *8*(3), 410–415. https://doi.org/10.23834/isrjournal.1342255

Lafifa, F., Rosana, D., Suyanta, S., Nurohman, S., & Dwi Astuti, S. R. (2023). Integrated STEM Approach to Improve 21st Century Skills in Indonesia: A Systematic Review. *International Journal of STEM Education for Sustainability*, *3*(2), 252–267. https://doi.org/10.53889/ijses.v3i2.219

Lee, G.-G., & Zhai, X. (2024). Using ChatGPT for Science Learning: A Study on Pre-service Teachers' Lesson Planning. *IEEE Transactions on Learning Technologies*, *17*, 1643–1660. https://doi.org/10.1109/TLT.2024.3401457

Leon, C., Lipuma, J., & Oviedo-Torres, X. (2025). Artificial intelligence in STEM education: A transdisciplinary framework for engagement and innovation. *Frontiers in Education*, *10*, 1619888. https://doi.org/10.3389/feduc.2025.1619888

Lusianti, E. F., Sari, Y., & Budiman, B. (2024). Systematic Literature Review (SLR): Penerapan Media Pembelajaran Berbasis Digital Pada Pembelajaran Bahasa Indonesia. *EUNOIA (Jurmal Pendidikan Bahasa Indonesia)*, *4*(1), 85–101.

Mai, N. T., Fang, Q., & Cao, W. (2025). Measuring Student Trust and Over-Reliance on AI Tutors: Implications for STEM Learning Outcomes. *International Journal of Social Sciences and English Literature*, *9*(12), 11–17. https://doi.org/10.55220/2576-683x.v9.799

Miller, J. D. (2022). Public understanding of science and technology in the Internet era. *Public Understanding of Science*, *31*(3), 266–272. https://doi.org/10.1177/09636625211073485

Noor, F. M. (2024). Trends And Opportunities In Fun Science Learning For Early Childhood: A Bibliometric Analysis (2014–2023). *ThufuLA: Jurnal Inovasi Pendidikan Guru Raudhatul Athfal*, *12*(2), 213–230. https://doi.org/10.21043/thufula.v12i2.29214

Noor, F. M., Rahayu, A., Handayani, N., & Anwari, M. K. (2022). Global Trend of Science Edutainment Research in The Last Ten Years. *Thabiea : Journal of Natural Science Teaching*, *5*(2), 204–215.

Olatunbosun Bartholomew Joseph & Nwankwo Charles Uzondu. (2024). Integrating AI and Machine Learning in STEM education: Challenges and opportunities. *Computer Science & IT Research Journal*, *5*(8), 1732–1750. https://doi.org/10.51594/csitrj.v5i8.1379

Prasetyo, D. R., Budhi, H. S., & Aryani, L. D. (2025). Creative Thinking Skills of Science Teacher Candidates in Making Biobatteries through STEM Project Based Learning. *Asia Research Network Journal of Education*, *5*(1), 1–14.

Rosario, J. (2025). * Memorization is not Enough: Why Critical Thinking is Key in Science * (SSRN Scholarly Paper 5282007). Social Science Research Network. https://doi.org/10.2139/ssrn.5282007

Saija, M., Rahayu, S., Fajaroh, F., & Sumari, S. (2022). Enhancement of High School Students' Scientific Literacy Using Local-Socioscientific Issues in OE3C Instructional Strategies. *Jurnal Pendidikan IPA Indonesia*, *11*(1), 11–23. https://doi.org/10.15294/jpii.v11i1.33341

Sukmawati, W., & Wahjusaputri, S. (2024). Integrating RADEC Model and AI to Enhance Science Literacy: Student Perspectives. *Jurnal Penelitian Pendidikan IPA*, *10*(6), 3080–3089. https://doi.org/10.29303/jppipa.v10i6.7557

Szarka, K., & Borovicza, B. (2023). FORMATIVE ASSESSMENT TECHNIQUES SUPPORTING SCIENCE CONCEPTUAL LEARNING. *INTED2023 Proceedings*, 957–966. 17th International Technology, Education and Development Conference. https://doi.org/10.21125/inted.2023.0296

*Teaching STEM in 2025: Where Did the Curiosity Go?* (2025, April 25). [Reddit Post]. R/Professors. https://www.reddit.com/r/Professors/comments/1k7ubud/teaching_stem_in_2025_where_did_the_curiosity_go/

Tsakeni, M., Nwafor, S. C., Mosia, M., & Egara, F. O. (2025). Mapping the Scaffolding of Metacognition and Learning by AI Tools in STEM Classrooms: A Bibliometric–Systematic Review Approach (2005–2025). *Journal of Intelligence*, *13*(11), 148. https://doi.org/10.3390/jintelligence13110148

Uban Subandi & Supardi Us. (2024). Integrasi Teknologi AI dalam Pembelajaran STEM di Sekolah Menengah: Perspektif Personalisasi, Tantangan, dan Implikasi. *Bilangan : Jurnal Ilmiah Matematika, Kebumian dan Angkasa*, *2*(6), 89–104. https://doi.org/10.62383/bilangan.v2i6.320

Universitas Negeri Padang, Padang, Indonesia, Irfan, D., Watrianthos, R., & Nur Bin Yunus, F. A. (2025). AI in Education: A Decade of Global ResearchTrends and Future Directions. *International Journal of Modern Education and Computer Science*, *17*(2), 135–153. https://doi.org/10.5815/ijmecs.2025.02.07

van Eck, N. J., & Waltman, L. (2019). *VOSviewer Manual*. Universiteit Leiden.

Xu, W., & Ouyang, F. (2022a). The Application of AI Technologies in STEM Education: A Systematic Review from 2011 to 2021. *International Journal of STEM Education*, *9*(1), 59. https://doi.org/10.1186/s40594-022-00377-5

Xu, W., & Ouyang, F. (2022b). The application of AI technologies in STEM education: A systematic review from 2011 to 2021. *International Journal of STEM Education*, *9*(1), 59. https://doi.org/10.1186/s40594-022-00377-5

Yanuarti, E. A., & Suprapto, N. (2021). Ten Years of Research on History of Science (Physics): A Bibliometric Analysis. *Studies in Philosophy of Science and Education*, *2*(1), 7–16. https://doi.org/10.46627/sipose.v2i1.66

Yatim, M., Fitri, E., Liantori, B., Tunnisa, S., & Amir, F. (2024). Implementasi Pendekatan STEM pada Kurikulum Merdeka di SDN 215/X Bukit Tempurung Tanjung Jabung Timur. *Pendas: Jurnal Ilmiah Pendidikan Dasar*, *09*(4).

Zhai, X. (2023). ChatGPT for Next Generation Science Learning. *XRDS*, *29*(3), 42–46. https://doi.org/10.1145/3589649