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The trend of science education research post-COVID-19 pandemic

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Abstract Science education is an important field that drives technological progress. However, science is still perceived by students and society as a complex and abstract field. Therefore, information regarding current trends in science education is needed to adapt to the current situation. This study aims to explore the ongoing trends in the past ten years and post-COVID-19 pandemic based on Scopus data. This research is a bibliometric analysis using the Scopus database. A bibliometric analysis was conducted with the help of specific software (MS Excel, Datawrapper, and VOSviewer). The Scopus database was used to find articles on science education. The articles had to be published between 2015 and 2024. Data collection was obtained by searching based on the TITLE of science education in Scopus and carried out four times by comparing International (all countries) and International (Indonesia) indexed journals in 2015 - 2024 and 2022-2024 (post-COVID). Then, the metadata was saved in the form of CSV and RIS to be analyzed using MS Excel, Datawrapper, and VOSviewer to visualize it. The findings show that the United States dominates research related to science education post-COVID-19 pandemic (2022-2024), while Indonesia is ranked 10th. Meanwhile, AIP Conference Proceedings is the most published publication source (Scopus) related to science education for all countries, including Indonesia. The number of Scopus-indexed article publications at the international level for all countries and Indonesia generally shows an increasing trend from 2015 to 2024. However, Indonesia experienced a decline in 2020, which coincided with the COVID-19 pandemic, and a significant decline in 2022, the first year post-COVID-19 pandemic.

Keywords: bibliometric analysis, science education development, Indonesia, scopus

1. Introduction

The COVID-19 pandemic affected almost all students worldwide, causing significant disruptions to the global education system (Jacques et al., 2023; Aristovnik et al., 2020; d'Orville, 2020). The quick shift to distance learning using various media such as radio, television, the internet, and even conventional postal services reflects the extent to which institutions and educators can adapt to unforeseen emergencies. However, most of these solutions are temporary and aimed at maintaining educational continuity rather than addressing the need for structural changes in learning systems. Nevertheless, the pandemic provides excellent opportunities and potential for educational innovation and demands structural changes in the learning system after the COVID-19 pandemic, especially in the field of science education (Ammar et al., 2024; Zhao & Watterston, 2021; da Silva et al., 2021).

Science education improves scientific and technological literacy (e.g., Fortus et al., 2022; Shatri, 2020; Xie et al., 2020). Science also serves as a means to foster scientific thinking skills (Kurz et al., 2021). Restrictions on hands-on experimental activities and laboratory practices have been a significant challenge during the pandemic, even though they are essential for science learning. However, this situation encourages the accelerated application of new technologies, such as virtual reality (VR) and augmented reality (AR), that enable interactive and accessible learning experiences (AlGerafi et al., 2023; Caboni & Pizzichini, 2022). Therefore, mapping science education research trends, both globally and regionally, is important to understand the pandemic's long-term impact and strategize future education.

Various studies on science education have been conducted over the past decades (e.g., Kalogiannakis et al., 2021; Li et al., 2020; Arici et al., 2019). However, no studies have specifically examined trends in science education after the COVID-19 pandemic. For example, Chang et al. (2010) evaluated science education research trends from 1990 to 2007 in the Journal of Science Education and Technology. They found that topics such as Conceptual Change and Concept Mapping dominated despite a decline in the early 2000s. Meanwhile, research by Susilayati et al. (2024) focused on the trends and contributions of science education during the pandemic (2018-2021) in the journal Review of Education. They concluded that contextual learning dominated at the beginning of the pandemic, while the theme of 'teaching' became the primary focus of future research.

However, the study did not fully address developments post-pandemic (2022-2024) and over the past decade (2015-2024). Therefore, this study is critical and can become an important reference for future research.

According to data compiled from Scopus accessed on January 8, 2025, during the 2015-2024 period, 296 papers came from Indonesia, with 9,262 papers in internationally indexed journals from all countries. For the more recent period, 2022-2024, the number of global papers reached 3,584, while 120 papers came from Indonesia. In the academic world, publications are an important resource for academic learning and research, especially from globally indexed journals.

Scopus is a reputable database used as a point of reference by world scholars to announce their research findings (e.g., Singh et al., 2021; Kipper et al., 2020). Nevertheless, publishing in Scopus-indexed journals is difficult because research interests must adhere to current developments and trends. Research shows that following emerging research trends can increase the probability of publication (Prahani et al., 2022; Echchakoui, 2020; Aksnes & Sivertsen, 2019). This points to the importance of understanding the direction of global research trends, particularly in science education.

Based on the above background, an examination of the research topics in the field of science education, both at the global level and in Indonesia, is essential to find out the direction of trends after the COVID-19 pandemic (2022-2015) and over the past decade (2015-2025). To answer the focus of the problem, this research asks the following main questions:

RQ1: What is the trend of countries contributing to international publications in science education research over a decade (2015-2024) and post-COVID-19 pandemic (2022-2024)?

RQ2: How is the trend of publications by year, document type, source type, source title, affiliation, and keywords in science education research over a decade (2015-2024) and post-COVID-19 pandemic (2022-2024) for all countries and Indonesia?

RQ3: How are the visualization trends of science education research over a decade (2015-2024) and post-COVID-19 pandemic (2022-2024) for all countries and Indonesia?

RQ4: What are the findings and recommendations of the most cited articles over a decade (2015-2024) and post-COVID-19 pandemic (2022-2024) for all countries and Indonesia?

This research has adopted bibliometrics as a powerful tool to map this vast and complicated research field in education science. Bibliometric research facilitates a broad and non-biased analysis of growth trends, topics, and key findings (Jagadeeswari & Das, 2024). Multiple tools were utilized in the bibliometric Analysis of this research to screen a full review of the existing literature on this particular topic. The analysis findings are hoped to guide the research developments and act as a precious reference for emerging researchers to identify and construct a strong base for their studies.

2. Materials and Methods

The research type employed is bibliometric, making use of the Scopus database. This research utilizes bibliometric analysis, which has been proven effective in discovering new things and emerging research trends (e.g.Prahani et al., 2022; Ghorbani et al., 2021; Chen et al., 2021). The data was obtained by searching based on science education titles in Scopus. This data was compiled based on four categories by comparing internationally indexed journals across all countries and Indonesia over a decade (2015–2024) and post-COVID-19 pandemic (2022–2024). Data was collected on January 8, 2025, using the flowchart in Figure 1.

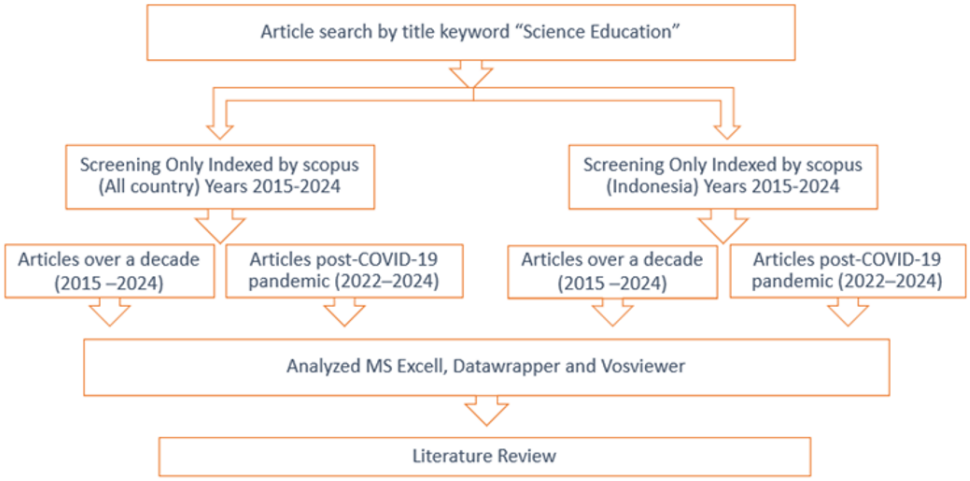


Figure 1 Flowchart research.

Figure 1 shows the research process, where data collection began with a decade-long search of articles in the Scopus database for all countries and Indonesia. Using the title "Science Education," pubyear "2015-2024," and Affilcountry "All countries," 9,262 documents were obtained, and when Affilcountry "Indonesia" was selected, 296 documents were obtained.

Next, post-pandemic data was collected using the title "Science Education," publication year "2022-2024," and affiliation country "All countries," yielding 3,584 documents, and when the affiliation country was set to "Indonesia," 120 documents were obtained. The metadata from the above search results was saved in CSV and RIS formats for further analysis. The data was analyzed using MS Excel, Datawrapper, and VOSviewer to visualize it in more appealing formats, such as tables, graphs, diagrams, and maps (Bukar et al., 2023; Prahani et al., 2022; Tamala et al., 2022). In recent years, there have been numerous studies demonstrating the effectiveness of VOSViewer in research indexed by Scopus (e.g., Martins et al., 2024; Munir et al., 2022; Prahani et al., 2022).

3. Results and Discussion

3.1. The trend of countries contributing to international publications of science education research over a decade (2015-2024) and post-COVID-19 pandemic

Science education research topics recorded in Scopus for a decade (2015-2024) were from 147 countries, and after the Covid-19 pandemic (2022-2024), were from 125 countries. The most productive countries in international publications of science education research are shown in Figure 2.

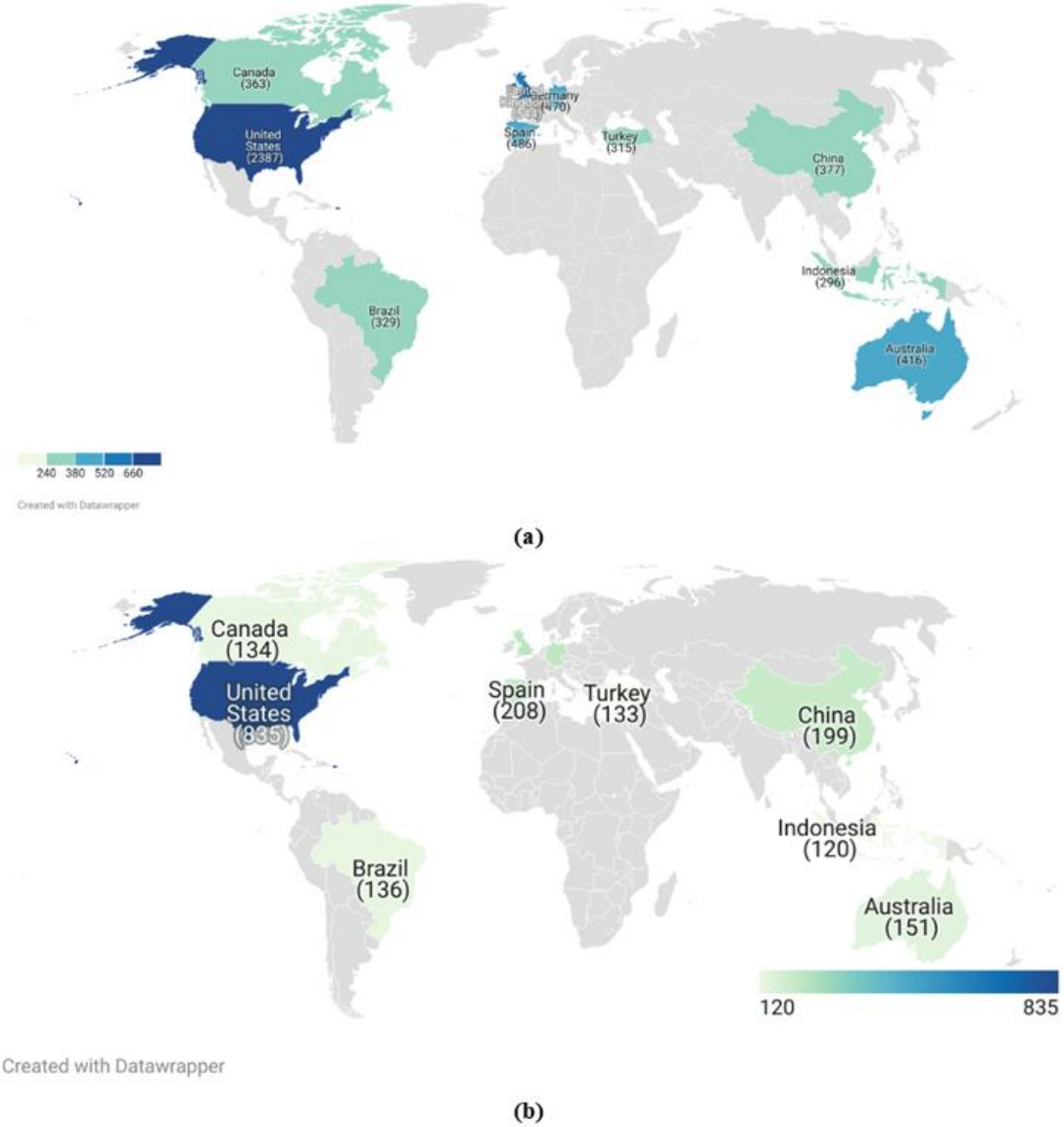


Figure 2 Top 10 countries contributing to science education research over a decade (a) and post-COVID-19 pandemic (b).
Source: Author's visualization based on Scopus database (2025).

Figure 2 shows the trend of the most productive countries in science education research publications. For a decade (Figure 2.a), the first rank was occupied by the United States with 2387 publications and followed by the United Kingdom, 544 publications, Spain, 486 publications, Germany, 470 publications, Australia, 416 publications, China, 377 publications, Canada,

363 publications, Brazil, 329 publications, Turkey, 315 publications, and ranked 10th by Indonesia with 296 publications. After the COVID-19 pandemic (Figure 2.b), the trend of the most productive countries, the first rank remains occupied by America, with 835 publications. The next rank is the United Kingdom with 227 publications, Germany 219 publications, Spain 208 publications, China 199 publications, Australia 151 publications, Brazil 136 publications, Canada 134 publications, Turkey 133 publications, and Indonesia remains ranked tenth, with 120 publications. Both for a decade (2014-2024) and after the COVID-19 pandemic (2022-2024), the first and 10th rank trends are occupied by the same countries, namely the United States and Indonesia. These results are consistent with findings from bibliometric analysis across all education-related domains, which show that countries such as the United States have maintained their dominant position. In contrast, other countries have progressively improved their scientific track records (Hallinger et al., 2024; Chen, 2023; Sulistiawati et al., 2023).

3.2. The Trends in international publication distribution by year, document type, source type, source title, affiliation, and keywords in science education research (all countries and Indonesia) over a decade (2015-2024) and post-COVID-19 pandemic (2022-2024)

Trends in international publication distribution by year

The Scopus database relevant to science education for a decade (2015-2024) contained 9262 documents for all countries and 296 documents for Indonesia. Then, after the COVID-19 pandemic (2022-2024), all countries have 3584 documents, while Indonesia has 120 documents. The following data is presented by year in Figure 3.

Figure 3 International publication distribution trends per year (all countries and Indonesia) over a decade (2015-2024) and after the Covid-19 pandemic (green block).
Source: Author's analysis based on Scopus database (2025).

Figure 3 shows that science education publications over a decade (2015-2024) for all countries show a consistent increasing trend from 2015. A substantial increase occurred in 2020 (during the COVID-19 pandemic). These results align with the findings of research conducted by Susilawati (2023), which revealed a continuous increase in the volume of science education from the 1970s to 2021. Several contributing factors, including technological advances, curriculum reform, and the impact of COVID-19, have been identified. Other studies have found that COVID-19 has been a significant catalyst for the growth of research on online and technology-based education (Cretu & Ho, 2023; Zhang et al., 2022; Abu Talib et al., 2021).

On the contrary, Indonesia experienced a fluctuation with a significant decline in 2020 and a sharp decline in 2022 (14 fewer documents compared to the previous year). This difference can be attributed to several external factors, including the onset of the COVID-19 pandemic, which shifted the government's focus to handling the health crisis, causing delays in research and publication activities. Additionally, in 2021, a restructuring of national research institutions occurred, resulting in administrative transitions, budget transfers, and the redistribution of human resources, which impacted the publication of research (Muchson et al., 2024; Kardoyo et al., 2025).

Trends in international publication document types, source type, and source title

Trends in document type, source type, and source title of international publications in science education research in the Scopus database over a decade (2015-2024) and after the covid pandemic (2022-2024) for all countries and Indonesia are shown in Figures 4, 5, and 6.

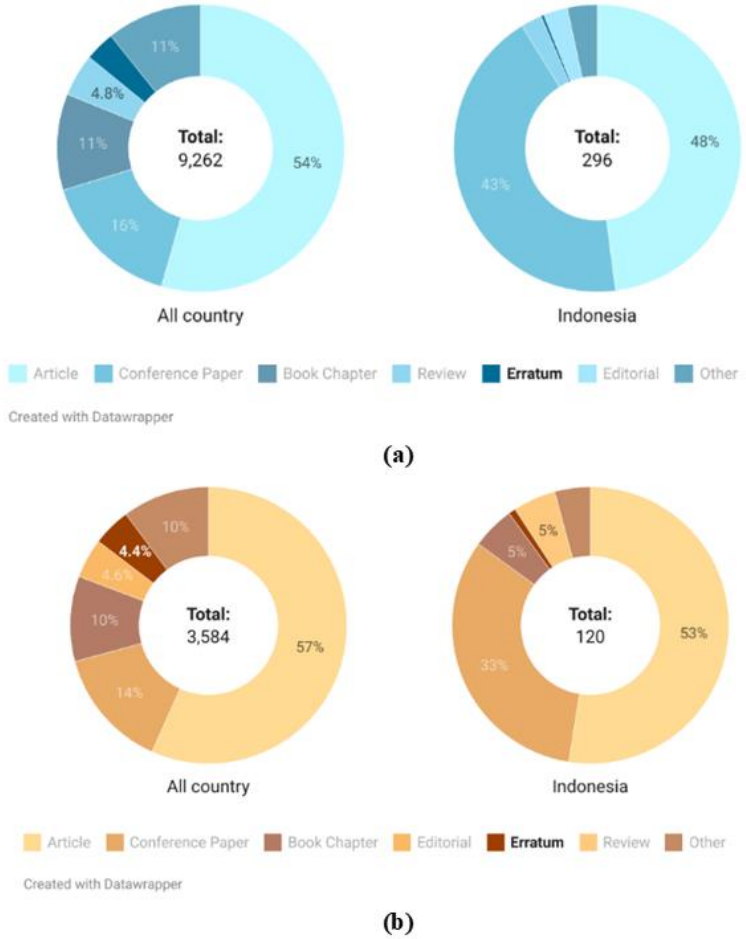


Figure 4 Document type research on science education over a decade (a) and after the COVID-19 pandemic (b).
Source: Author's analysis based on Scopus database (2025).

Figure 4 explains the types of documents for a decade (2015-2024) and after the Covid-19 pandemic (2022-2024) for all countries and Indonesia. Based on the type of publication document, for all countries and Indonesia, the type of document is dominated by articles. Detailed information expanded by source type can be seen in Figure 5.

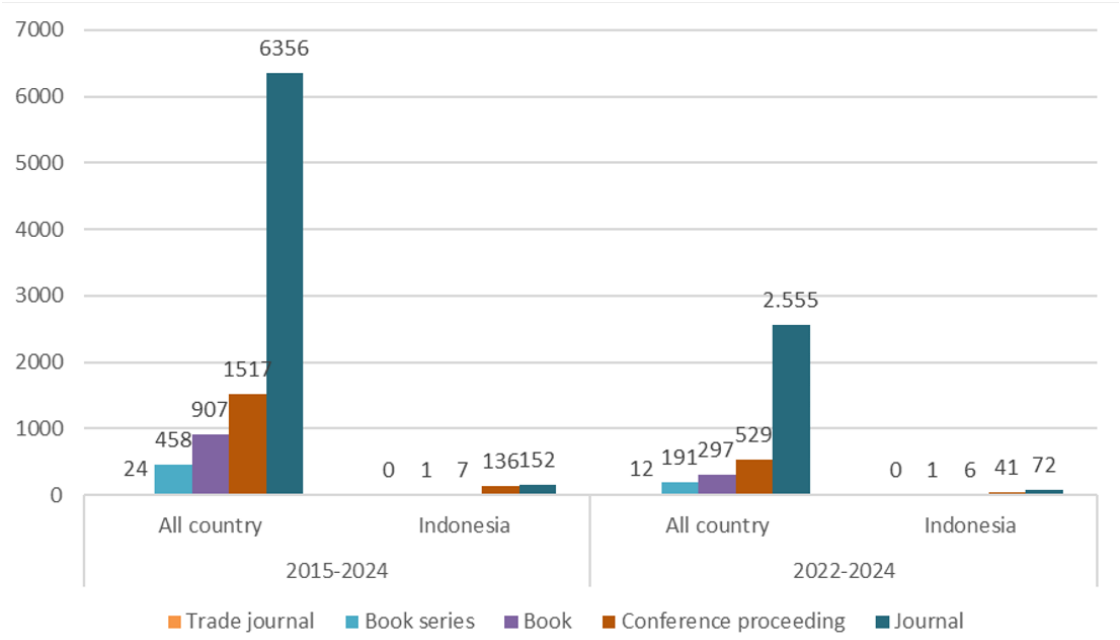


Figure 5 Documents source research on science education over a decade (2015-2024) and after the COVID-19 pandemic (2022-2024).
Source: Author's analysis based on Scopus database (2025).

Figure 5 illustrates international publications on science education research topics over a decade (2015 - 2024) and after the COVID-19 pandemic (2022 - 2024) for all countries and Indonesia. In international publications in all countries, including Indonesia, the types of sources used are dominated by journals. In addition, it continues to experience growth based on title source-based data, as seen in Table 1.

Table 1 Document source title research on science education (top 10).

Source Title (2015-2024)				Source Title (2022-2024)			
All country	Total	Indonesia	Total	All country	Total	Indonesia	Total
Journal Of Physics Conference Series	178	Journal Of Physics Conference Series	67	AIP Conference Proceedings	84	AIP Conference Proceedings	2 8
Cultural Studies Of Science Education	174	Aip Conference Proceedings	38	Science And Education	74	Journal Of Engineering Science And Technology	1 1
Science And Education	139	Jurnal Pendidikan IPA Indonesia	15	Education Sciences	53	Eurasia Journal Of Mathematics Science And Technology Education	5
Aip Conference Proceedings	127	Journal Of Engineering Science And Technology	12	Frontiers In Education	50	Iop Conference Series Earth And Environmental Science	4
ACM International Conference Proceeding Series	106	Journal Of Turkish Science Education	10	Cultural Studies Of Science Education	46	Journal Of Turkish Science Education	4
International Journal Of Science Education	98	Iop Conference Series Earth And Environmental Science	9	Sustainability Switzerland	45	Asean Journal Of Science And Engineering	2
Education Sciences	92	Eurasia Journal Of Mathematics Science And Technology Education	6	ACM International Conference Proceeding Series	39	E3s Web Of Conferences	2
Sustainability Switzerland	81	International Journal Of Evaluation And Research In Education	5	Lecture Notes In Educational Technology	37	Eurasian Journal Of Educational Research	2
Research In Science Education	76	ACM International Conference Proceeding Series	4	International Journal Of Science Education	36	International Journal Of Advanced And Applied Sciences	2
Journal Of Baltic Science Education	74	E3s Web Of Conferences	3	ASEE Annual Conference And Exposition Conference Proceedings	31	International Journal Of Emerging Technologies In Learning	2

Table 1 shows the science education research topics (Top 10) for a decade (2015 - 2024) and after the COVID-19 pandemic (2022 - 2024) for all countries and Indonesia. Based on the Source Title in all countries and Indonesia, for a decade (2015 - 2024), the dominant one is Journal of Physics Conference Series, while after the COVID-19 pandemic (2022 - 2024), the dominant one is AIP Conference Proceedings.

The results of the document type analysis (Figure 4) indicate that journal articles are the most common type of publication, both globally and in Indonesia. This confirms the role of peer-reviewed journals as the main channel of scientific communication in the field of science education (Abramo et al., 2023; Kyvik & Aksnes, 2015). In addition, the publication sources (Figure 5) indicate that conference proceedings also play a significant role, both during the last decade (2015-2024) and during the post-COVID-19 pandemic period. The Journal of Physics Conference Series ranked first during the last decade, while AIP Conference Proceedings ranked first during the post-COVID-19 pandemic period. The dominance of conference proceedings shows the role of conferences as a means of faster research dissemination, when access to international journals is increasingly limited (Falk & Hagsten, 2021; Deeken et al., 2020).

Trends in international publication affiliation and keywords

Based on documents obtained from Scopus, the top affiliations of Science Education Research Topics for a decade (2015-2024) and after the COVID-19 pandemic (2022-2024) in all countries and Indonesia are shown in Table 2.

Table 2 shows that over the last decade (2015-2024), globally, the three affiliations with the most publications were the University of Toronto, Stanford University, and Michigan State University. After the COVID-19 pandemic (2022-2024), Oxford

University ranked first globally. In Indonesia, over the past decade (2015-2024) and post-COVID-19 (2022-2024), the Indonesia University of Education has consistently been the primary contributor. In Indonesia, the average number of publications from each institution is still low (1-10 publications per year). This condition suggests that research capacity and international research networks require improvement, as the intensity of research networks affects citations and visibility in international publications (Wang et al., 2024; Kwiek, 2021; Matthews et al., 2020).

Table 2 Affiliations in the research field of science education (top 10).

All country	Total	Indonesia	Total	All country	Total	Indonesia	Total
University of Toronto	70	Universitas Pendidikan Indonesia	57	University of Oxford	38	Universitas Pendidikan Indonesia	31
Stanford University	62	Universitas Negeri Malang	24	Universitas Pendidikan Indonesia	31	Universitas Negeri Malang	17
Michigan State University	60	Universitas Negeri Surabaya	21	Michigan State University	29	Universitas Negeri Surabaya	8
Universitas Pendidikan Indonesia	57	Universitas Negeri Semarang	19	University of Toronto	27	Universitas Negeri Yogyakarta	7
University of Oxford	55	Universitas Negeri Jakarta	19	Nanyang Technological University	23	Universitas Negeri Jakarta	6
Helsingin Yliopisto	51	Universitas Negeri Yogyakarta	18	Universidade de São Paulo	22	Universiti Teknologi Malaysia	5
Monash University	51	Universitas Sebelas Maret	14	The University of Texas at Austin	22	Universitas Negeri Semarang	5
University of Michigan, Ann Arbor	51	Universitas Negeri Padang	10	Monash University	21	Universitas Sultan Ageng Tirtayasa	5
Universidade de São Paulo	50	Universitas Negeri Makassar	9	University of Michigan, Ann Arbor	21	Universitas Sebelas Maret	4
Universidad de Granada	50	Universitas Jambi	8	Universitetet i Oslo	20	Institut Teknologi Bandung	3

Keyword Science Education Research Topics for a decade (2015-2024) and after the COVID-19 pandemic (2022-2024) across countries and Indonesia, based on documents obtained from Scopus, are shown in Table 3.

Table 3 shows the keywords in research publications on the topic of science education for a decade (2015-2024) and after the COVID-19 pandemic (2022-2024) for all countries and Indonesia. For a decade (2015-2024), for all countries, the top keyword is education (1267), while in Indonesia, it is science education (65). After the COVID-19 pandemic (2022-2024), the top keyword for all countries and Indonesia is science education. Figure 6 shows the most frequently used keywords in research publications on science education topics for all countries over the decade (2015-2024) and after the COVID-19 pandemic (2022-2024).

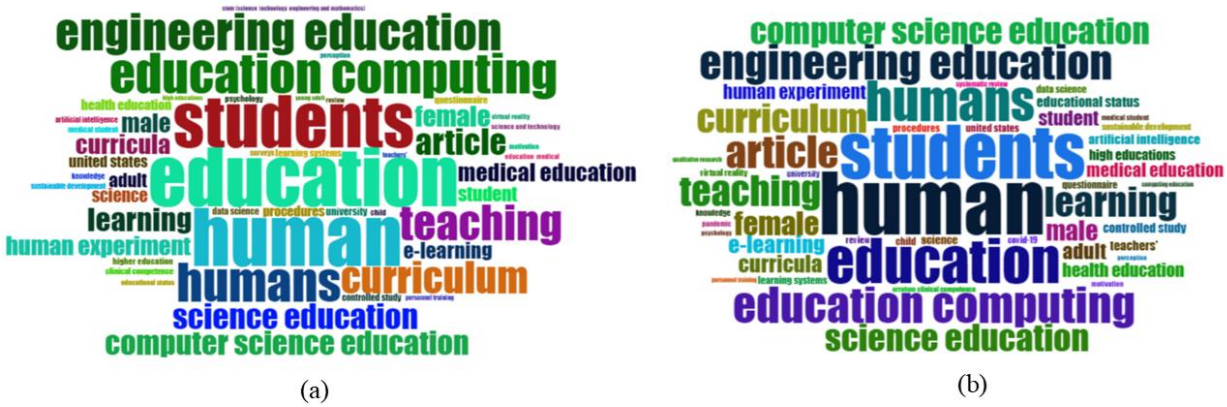
The most frequently used words for a decade are education, human, students, education computing, humans, engineering education, teaching, curriculum, article, and science education. Meanwhile, after the Covid-19 pandemic, they are human, students, education, humans, education computing, engineering education, article, teaching, learning, and curriculum. The font size indicates words that are frequently used in this topic.

Several keywords have experienced an increase in popularity following the COVID-19 pandemic, including "human," "students," "male," "female," "adult," "health education," "artificial intelligence," "e-learning," "virtual reality," "pandemic," "engineering education," and "medical education." This shows that interest in issues related to these keywords has increased after the pandemic. These issues include: the integration of technology (computing, AI, e-learning, and virtual reality), interdisciplinarity (engineering education and medical education), health issues and human experience in learning, and student inclusivity (human, students, male, female, and adult). Recent studies emphasise that the pandemic has accelerated the

adoption of digital learning while highlighting disparities in access and student health (Ndzinisa & Dlamini, 2022; Hass et al., 2023).

Table 3 Keyword research on science education (top 10).

Keyword (2015-2024)				Keyword (2022-2024)			
All country	Total	Indonesia	Total	All country	Total	Indonesia	Total
Education	1267	Science Education	65	Science Education	533	Science Education	25
Science Education	1199	Students	57	Education	405	Bibliometric	8
Human	942	Education Computing	31	Human	394	Literature Review	6
Students	881	Engineering Education	22	Students	346	Education	6
Education Computing	648	STEM (science, Technology, Engineering And Mathematics)	20	Humans	251	Science	5
Humans	629	Education	20	Education Computing	226	Indonesia	5
Engineering Education	621	Teaching	19	Engineering Education	224	Engineering Education	5
Teaching	563	Indonesia	19	Article	203	Bibliometric Analysis	5
Computer Science Education	451	Surveys	16	Computer Science Education	194	Science Learning	4
Article	424	Science Teachers	16	Teaching	190	Project-based Learning	4



(a) (b)

Figure 5 Most relevant keywords over a decade (a) and after the Covid-19 pandemic (b).
Source: Author's visualization based on Scopus database (2025).

3.3. Visualization trends of science education research (all countries & Indonesia) over a decade (2015-2024) and post-COVID-19 pandemic (2022-2024)

Visualization of Science Education Research Trends for all countries and Indonesia over a decade (2015-2024)

International publications in the Scopus database for all countries for a decade (2015 - 2024) contained 9262 documents related to science education topics. Then, we visualized the trends of research topics with the help of VOSviewer. Research trends in science education are shown in Figures 6, 7, and 8.

Figure 6 is a network visualization of all Scopus data-based research on science education over a decade (2015-2024). The results of this visualization are displayed in six clusters (red, green, blue, yellow, purple, and light blue). The first cluster (red color) is academic performance, active learning, application programs, artificial intelligence, assessment, augmented reality, behavioral research, bibliometric analysis, big data, blended learning, case-studies, china, citizen science, climate change, collaborative learning, computation theory, computational thinking, computational thinkings, computer aided instruction, computer games, computer programming, computer science, computer science course, computer science curricula, computer science education, computer science students, computer software, computing education, creativity, critical thinking, cs education, curricula, data mining, data science, data science education, data visualization, decision making, deep learning, design, developing countries, distance education, diversity, e-learning, ecology, economics, education computing, education research, educational development, educational technology, elementary schools, employment, engineering,

engineering and mathematics, engineering education, engineering research, environmental education, equity, evaluation, experiential learning, game-based learning, gamification, gender, general education, health, high educations, high school, higher education, higher education institutions, human computer interaction, inclusion, information management, information science, innovation, integration, internet of things, k-12, laboratories, learn+, learning environments, learning experiences, learning outcome, learning systems, literacy, literature review, literature reviews, machine learning, mathematics, mathematics education, middle school, motivation, nature of science, online learning, open science, pedagogy, personnel training, physics, primary education, primary schools, problem solving, professional aspects, professional development, project based learning, research questions, robotics, science and engineering, science and technology, science curriculum, science education, science learning, science teachers, science teaching, science technologies, scientific literacy, secondary education, secondary schools, serious games, societies and institutions, software, software design, software engineering, stem, stem (science, technology, engineering and mathematics), stem education, student engagement, students, surveys, sustainability, sustainable development, teacher education, teacher training, teachers', teaching, teaching and learning, teaching materials, teaching methods, technology, technology education, undergraduate, undergraduate education, undergraduate students, university sector, university students, virtual reality, visualization and web of science.

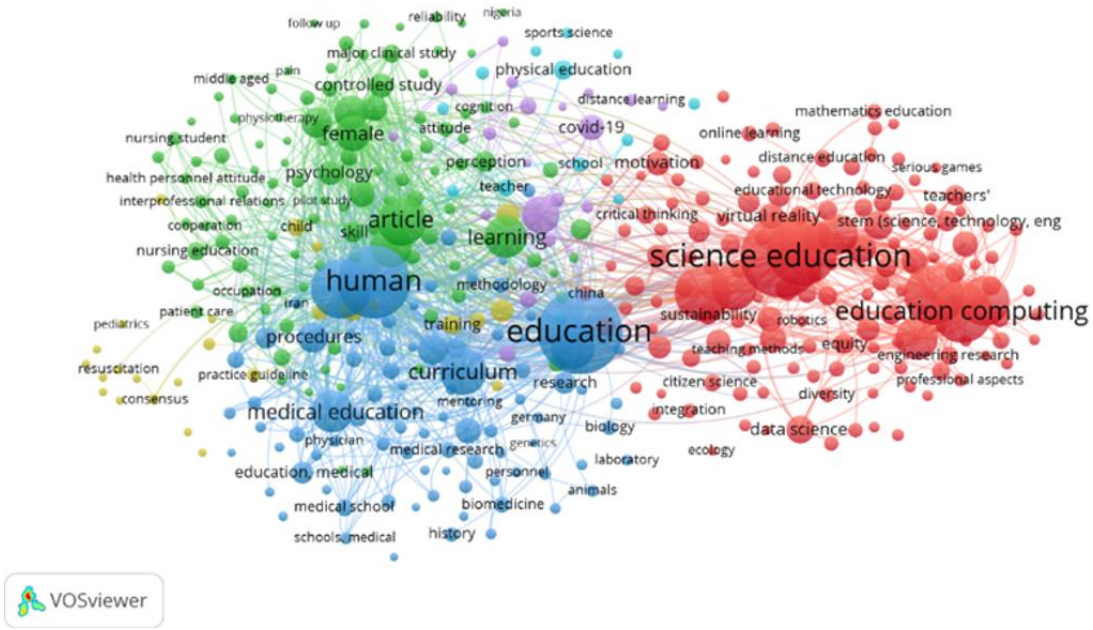


Figure 6 Network Visualization research trend in international science education (all countries).
Source: Author's visualization based on Scopus database (2025).

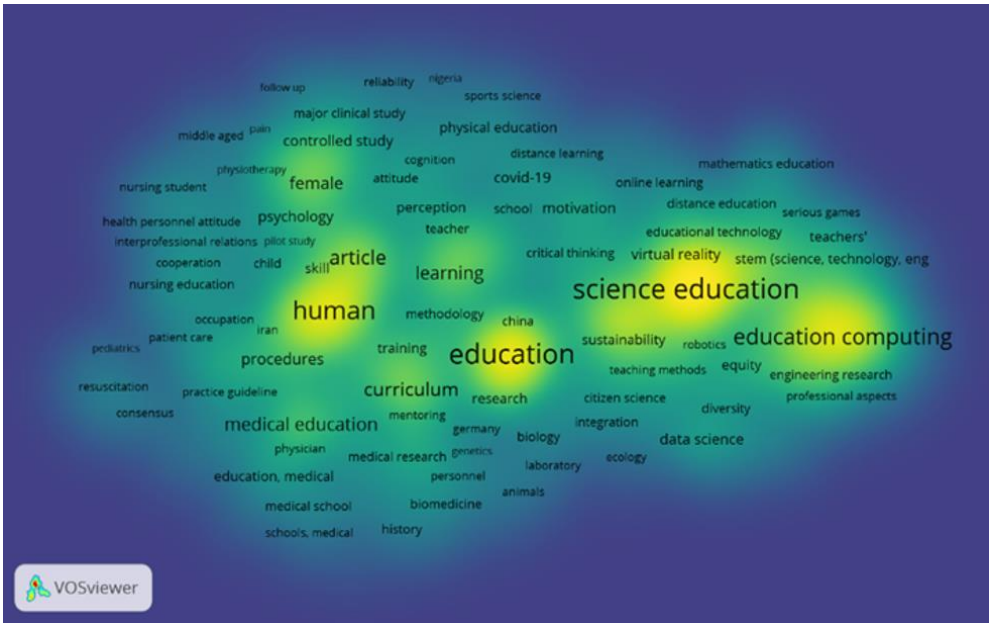


Figure 7 Density Visualization research trend in international science education (all countries).
Source: Author's visualization based on Scopus database (2025).

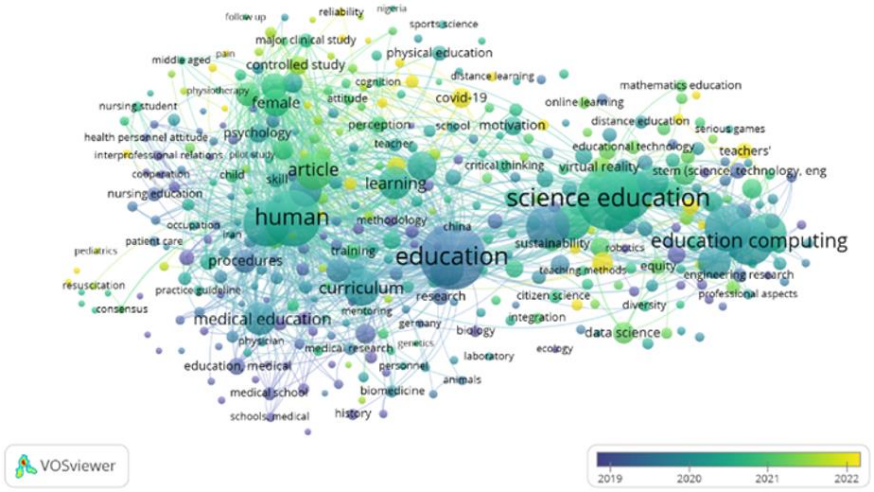


Figure 8 Overlay Visualization research trend in international science education (all countries).
Source: Author's visualization based on Scopus database (2025).

The second cluster (green color) is adolescent, adult, aged, anxiety, article, attitude, attitude of health personnel, attitude to health, awareness, behavioral science, chronic pain, clinical article, clinical competence, cognition, communication, competency-based education, conceptual framework, content analysis, controlled study, cooperation, cooperative behavior, cross-sectional studies, cross-sectional study, curriculum development, data analysis, dental education, dentistry, education, dental, education, nursing, education, nursing, baccalaureate, educational model, educational theory, ethics, female, follow up, health care, health care personnel, health education, health knowledge, attitudes, practice, health occupations, health personnel, health personnel attitude, health promotion, health science, health sciences, health student, human experiment, humanities, information processing, interdisciplinary education, interpersonal communication, interprofessional education, interprofessional relations, interview, learning, learning environment, likert scale, major clinical study, male, medical profession, middle aged, models, educational, nigeria, nursing, nursing education, nursing student, occupation, organization and management, outcome assessment, pain, patient care, patient education, perception, personal experience, philosophy, physiotherapy, pilot study, professional competence, professionalism, program development, program evaluation, psychology, public health, public relations, qualitative analysis, qualitative research, quantitative analysis, questionnaire, randomized controlled trial, reliability, reproducibility, reproducibility of results, responsibility, satisfaction, semi structured interview, skill, social sciences, sociology, students, health occupations, students, nursing, surveys and questionnaires, teamwork, thematic analysis, theoretical study, thinking, undergraduate student, validity, vocational education, wellbeing, workshop and young adult.

The third cluster (blue color) is academic achievement, accreditation, anatomy, animal, animals, australia, basic science, biological science disciplines, biology, biomedical research, biomedicine, brazil, career, chemistry, clinical education, clinical practice, continuing education, curriculum, delivery of health care, editorial, education, education program, education, graduate, education, medical, education, medical, graduate, education, medical, undergraduate, education, pharmacy, educational measurement, educational status, europe, evidence based practice, faculty, genetics, germany, government, graduate education, health care delivery, history, history, 20th century, human, humans, international cooperation, iran, laboratory, language, lifelong learning, medical education, medical research, medical school, medical society, medical student, medicine, mentoring, methodology, neuroscience, nonhuman, note, organization, peer review, personnel, pharmacist, physician, physiology, politics, postgraduate education, priority journal, procedures, publication, research, research design, research personnel, schools, medical, science, scientific literature, scientist, standards, statistics, statistics and numerical data, students, medical, translational research, trends, united kingdom, united states, universities, university and workforce. The fourth cluster (yellow color) is basic life support, cardiopulmonary resuscitation, child, consensus, diagnosis, emergency health service, emergency medical services, first aid, health care quality, heart arrest, implementation science, knowledge, leadership, pediatrics, practice guideline, quality control, quality improvement, quality of life, randomized controlled trial (topic), resuscitation, review, social media, systematic review, therapy, total quality management, and training. The fifth cluster (purple color) is achievement, comparative study, computer simulation, coronavirus disease 2019, COVID-19, distance learning, education, distance, epidemiology, feedback, feedback system, internet, pandemic, pandemics, problem based learning, problem-based learning, SARS-CoV-2, simulation, student, and tertiary education. The sixth cluster (light blue) is exercise, pedagogy, physical activity, physical education, primary school, publishing, school, schools, Spain, sport, sports, sports science, and teacher.

Figure 7 shows the Density Visualization with high intensity (yellow color) seen in several sections, namely, human, education, science education, education computing, article, curriculum, etc. There is potential for development in the future, namely virtual reality, sustainability, robotics, equity, data science, sports science, teacher, and critical thinking.

Figure 8 shows the Overlay Visualization of science education research trends. There are four colours: yellow, green, blue, and purple. You can see the dominant blue colour with its roots in science education research, and the indicator yellow colour is the research currently being conducted. The yellow cluster is teachers and artificial intelligence.

Over a decade (2015 - 2024), there were 296 Indonesian international publications on topics related to science education in the Scopus database. Then, we used VOSviewer to visualize the trends of these research topics. Research trends in science education are shown in Figure 9.

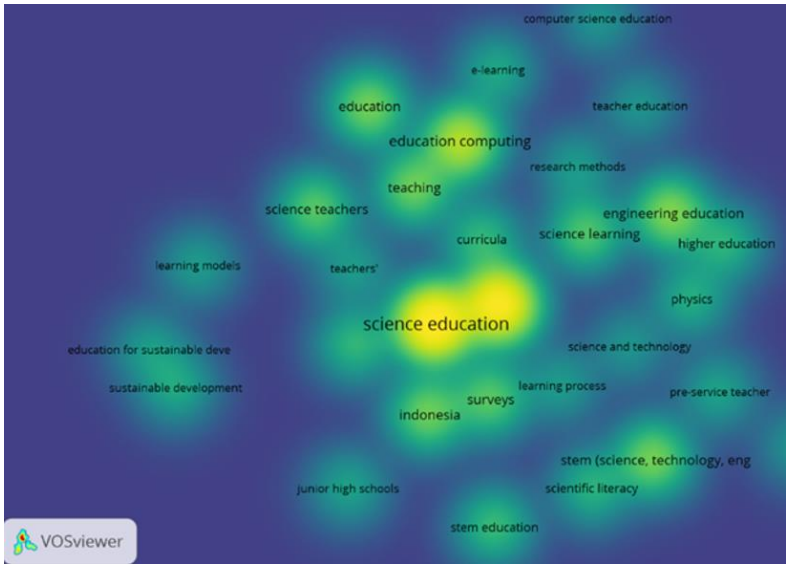


Figure 9 Density Visualization research trend in international science education (Indonesia).
Source: Author's visualization based on Scopus database (2025).

Figure 9 shows the Density Visualization with almost the same intensity as the bright colors. Colors consist of science education, education computing, education, teaching, science teachers, science learning, engineering education, surveys, and Indonesia. The network visualization resulted in five cluster colors (red, green, blue, yellow, and purple). Cluster one (red color) includes higher education, Indonesia, learning process, learning systems, physics, pre-service teacher, science and technology, science education, and teachers. Cluster two (green color) includes junior high schools, science, technology, engineering, mathematics, scientific literacy, STEM (science, technology, engineering, and mathematics), STEM education, students, and surveys. Cluster three (blue color) includes curricula, research methods, science learning, science teachers, teacher education, and teaching. Cluster four (yellow color) includes computer science education, e-learning, education, computing, and engineering education. Cluster five (purple color) includes education for sustainable development, learning models, and sustainable development. Overlay visualization of science education research shows four colors: Purple, blue, green, and yellow. The Purple color cluster comprises curricula, learning models, junior high schools, research methods, science and technology, and computer science education. The blue color cluster consists of education computing, surveys, STEM (science, technology, engineering, and mathematics), science teachers, and learning systems. The Green color cluster consists of STEM education, STEM (science, technology, engineering, and mathematics), and engineering education. The Yellow color cluster consists of education for sustainable development, sustainable development, science education, Indonesia, higher education, e-learning, and scientific literacy. This clarifies the relationship between them.

Based on global visualization over the past decade (2015-2024), dominant keywords appear in several clusters, such as science education, education computing, virtual reality, and STEM in the red cluster; human, education, curriculum, and medical education in the blue cluster; and learning, article, psychology, female, and several themes such as online, technology integration, and distance education in the green cluster. The size of the nodes indicates the frequency/centre of the keywords, and the thickness/sharpness of the lines indicates the proximity/correlation with these topics. The themes of science education and education computing are the most central and prominent, indicating that science education research focuses on these areas, while human, education, and medical education form a significant cluster on the other side. This visualization illustrates the shift in science education research from traditional methods to the integration of digital technology, computing, and online/virtual learning, as well as interdisciplinary approaches. This aligns with recent studies on the integration of media and digital technology, as well as interdisciplinarity in science education, which have seen a significant increase (Sırakaya & Alsancak Sırakaya, 2022; Momani et al., 2023; Fajri et al., 2024).

In Indonesia, the results of visualisation density, which is the most dense, include science education, followed by education computing, engineering education, education, teaching, science teachers, science learning, STEM, scientific literacy, learning processes, and surveys. Additionally, the overlay visualisation for the green and yellow colour clusters displays the latest trends, featuring keywords such as STEM Education, STEM, Engineering Education, Education for Sustainable Development, Sustainable Development, E-learning, and scientific literacy. Both visualization results show keywords that have been trending and the latest trends in science education research in Indonesia over the past decade (2015-2024). Several studies also support this issue, including a study conducted by Laksmiwati et al. (2023), which states that the Indonesian government provides substantial support for STE(A)M education by organising large-scale teacher training programs. In addition, a study conducted by Harjatanaya et al. (2025) demonstrates that a participatory approach, which empowers lecturers across departments in the development of ESD modules, enables the addressing of both local and global issues.

Visualization of Science Education Research Trends for all countries and Indonesia post-COVID-19 pandemic (2022-2024)

Research trends in the field of science education after the COVID-19 pandemic (2022-2024) are shown in Figure 10. In that period, for all countries, there were 3584 documents in the Scopus data. Then, researchers visualized the trend of research topics with the help of VOSviewer. Figure 10 is a visualization of all Scopus data-based research on science education after the COVID-19 pandemic (2022 - 2024). The visualization results show four color groups (red, green, blue, and yellow). The first clusters (red color) are adult, aged, article, attitude, career, clinical article, cognition, content analysis, controlled study, cross-sectional studies, cross-sectional study, female, health care, health care personnel, health education, health personnel, health science, health sciences, human experiment, interprofessional education, interview, learning environment, likert scale, major clinical study, male, middle aged, motivation, nursing education, nursing student, occupation, outcome assessment, patient education, perception, personal experience, psychology, qualitative research, quantitative analysis, questionnaire, reliability, reproducibility, reproducibility of results, semi structured interview, skill, students, nursing, surveys and questionnaires, tertiary education, thematic analysis, and young adult. The second cluster (green color) is artificial intelligence, augmented reality, chatgpt, computational thinkings, computer aided instruction, computer science, computer science education, computing education, critical thinking, curricula, curriculum development, data science, decision making, e-learning, education computing, educational technology, engineering, engineering and mathematics, engineering education, equity, gender, high educations, higher education, learn+, learning systems, machine learning, mathematics, mathematics education, pedagogy, personnel training, professional development, science, science and technology, science education, science technologies, stem, stem education, students, sustainability, sustainable development, teacher education, teacher training, teachers', teaching, technology, technology education, and virtual reality. The third cluster (blue color) is academic achievement, active learning, anatomy, biomedicine, clinical competence, coronavirus disease 2019, covid-19, curriculum, distance learning, editorial, education, education program, education, distance, education, medical, education, medical, undergraduate, educational measurement, educational status, epidemiology, faculty, human, humans, knowledge, learning, medical education, medical school, medical student, medicine, note, pandemic, pandemics, physician, problem based learning, problem-based learning, procedures, social media, student, students, medical, training, universities, and university. Cluster four (yellow color) is adolescent, advanced life support, basic life support, child, chronic pain, consensus, diagnosis, exercise, first aid, health promotion, implementation science, interpersonal communication, pediatrics, practice guideline, public health, research, resuscitation, review, school, schools, systematic review, teacher, therapy, united states, and workshop.

Density visualization with almost the same intensity. The ones that appear clearer (yellow color) are article, curriculum, education, education computing, e-learning, health education, humans, learning, science education, stem education, student, teaching. In Density Visualization, there are several words that are still unclear, some of which are sustainability and ChatGPT. It is hoped that in the future, the relationship between science education, sustainability, and AI will be clear. The overlay visualization of science education research trends has four colors: blue, purple, yellow, and green. The blue color cluster is dominant with the words adolescent, aged, basic life support, child, chronic pain, consensus, cross-sectional studies, diagnosis, health education, human experiment, middle-aged, patient education, pediatrics, review, and therapy. The purple color cluster is dominant with the words ChatGPT, curriculum development, education computing, education, distance, machine learning, and university. Yellow clusters are dominant with anatomy, COVID-19, education, medical, medical student, outcome assessment, pandemic, questionnaire, students, and medical. The green color cluster is dominant with words curricula, curriculum, education, e-learning, engineering, learning, mathematics education, personnel training, science education, STEM, students, sustainability, teachers, and technology.

In 2022-2024 (after the COVID-19 pandemic), there were 120 Indonesian international publications on science education in the Scopus database. Then, researchers visualized the trend of research topics with the help of VOSviewer. Research trends in the field of science education are illustrated in Figure 11, which is a visualization of all Indonesian research publications in the Scopus database in the field of science education after COVID-19 (2022 - 2024).

The network visualization results in four color clusters (red, green, blue, and yellow). Cluster one (red color) consists of bibliometrics, e-learning, and science education. Cluster two (green color) comprises bibliometric analysis, education, and science. Cluster three consists of education computing, and engineering education. Cluster four (yellow color) consists of bibliometric and literature review.

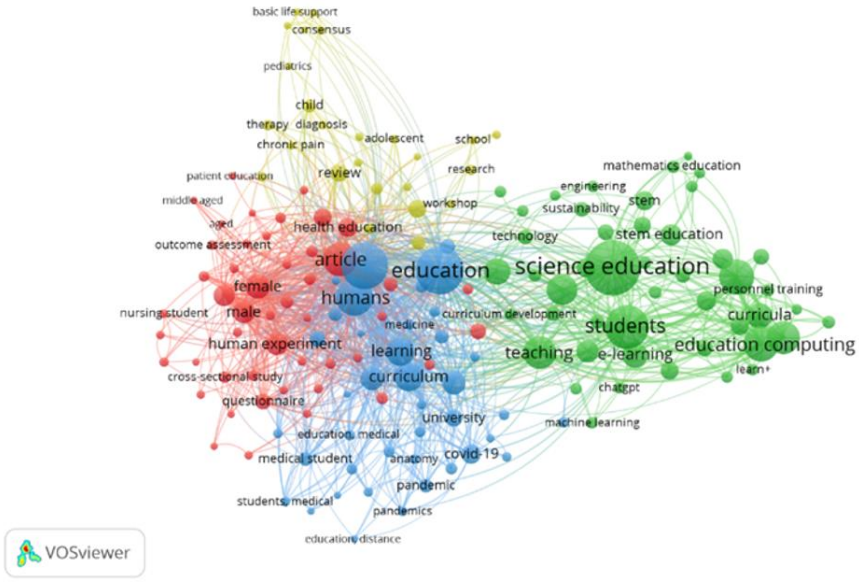


Figure 10 Network visualization research trend in international science education (all countries).
Source: Author's visualization based on Scopus database (2025).

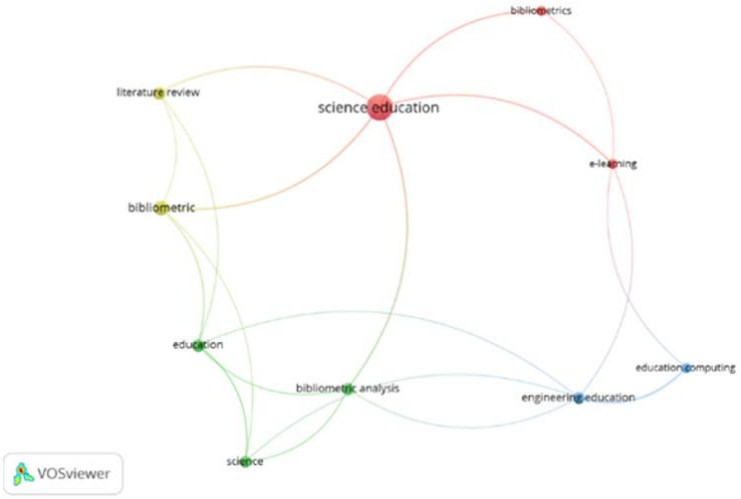


Figure 11 Network visualization research trend in international science education (Indonesia).
Source: Author's visualization based on Scopus database (2025).

The density visualizations with the highest to lowest yellowish intensity are science education, literature review, bibliometric, education, engineering education, bibliometric analysis, bibliometrics, science, education computing, and e-learning. The overlay visualization of science education research trends has five colors: purple, blue, green, and yellow. The purple cluster consists of literature review, e-learning, and bibliometric analysis. The blue cluster consists of the words science education. The green cluster consists of bibliometric, education, science and engineering education. The yellow cluster consists of the words bibliometrics and education computing.

Based on the results of global bibliometric visualisation after COVID-19 (2022-2024), global science education research trends emphasise the keywords science education, students, human, curriculum, education computing, and STEM. These topics have become more intensive since the COVID-19 pandemic. This indicates that global science education research post-COVID is focused on humans (students) affected by the COVID-19 pandemic (Jakubowski et al., 2025). Some of the focuses of this global research include: STEM issues, curriculum innovation, and AI in education (Li et al., 2020; Bond et al., 2021), digital learning adaptation, the use of virtual laboratories, and technology-based teaching strategies (Afrilyasanti & Basthomi, 2022; Radhamani et al., 2021).

In Indonesia, the results of post-COVID bibliometric visualisation (2022-2024) show that science education research trends in Indonesia are closely linked to bibliometrics, education computing, engineering education, and e-learning. The keywords bibliometrics and bibliometric analysis indicate an increase in Indonesian researchers' interest in literature mapping studies as a method for understanding the direction of science research development. Furthermore, the connection with e-learning reinforces the need to integrate digital technology into science learning, a trend driven by the pandemic's needs (Leal Filho et al., 2024; Christopoulos & Sprangers, 2021; Peterson et al., 2020). When compared to global trends post-pandemic

(2022-2024), there are similarities related to the topics of e-learning and digital/online learning, where the pandemic drove both Indonesia and the global community to strengthen the transformation in science education.

3.4. Findings and recommendations from the most cited articles (all countries & Indonesia) over a decade (2015-2024) and post-COVID-19 pandemic (2022-2024)

Over a decade (2015-2024), the most cited articles (top 5) based on the Scopus database, their findings, and recommendations in science education research are shown in Tables 4 and 5.

Table 4 Findings and recommendations top-cited articles (all countries) years (2015-2024).

No.	Cited by	Authors	Source title	Finding	Recommendations
1	5479	Taber (2018)	Research in Science Education	Many papers do not explain what an alpha value means or why a particular value is desired.	Future researchers can explain what they think the alpha statistic reflects and why it is informative. They can interpret alpha values in the context of their research, considering the expected dimensions and number of items, and Present alpha along with other complementary statistical measures.
2	1002	Burley et al. (2021)	Nucleic Acids Research	The RCSB Protein Data Bank has improved search features and data accessibility, allowing users to quickly find and explore more than 350 SARS-CoV-2 protein structures released quickly to support research and drug development during the COVID-19 pandemic.	Moving forward, researchers can utilise the improved search features and open access to 3D biostructure data to support drug discovery and vaccine development efforts, especially in the context of the COVID-19 pandemic.
3	659	Hirsh-Pasek et al. (2015)	Psychological Science in the Public Interest, Supplement	Interaction with vocabulary-focused apps can increase children's vocabulary from low-income families by 31% in two weeks.	In the future, other researchers could design apps that match the way children learn, focusing on principles that can increase educational benefits and creating interfaces that allow parents to control features that could be distracting.
4	645	Potkonjak et al. (2016)	Computers and Education	Results demonstrate the importance of evaluation criteria, highlight robotics as a complex engineering field, recognize the need for hands-on experience, and direct future research to improve virtual environments to support learning more effectively.	Going forward, researchers may consider: 1) refining the design and enriching the interactivity of the virtual environment so that it more closely resembles the actual laboratory experience; 2) encouraging online collaboration between students, teaching assistants, and lecturers within the virtual environment; 3) integrating the virtual laboratory with hands-on practice in the science laboratory to develop students' comprehensive skills.
5	602	Stoet & Geary (2018)	Psychological Science	The study found that while women are equal to or better at science literacy than men in many countries, women still earn fewer degrees in STEM fields. STEM career options are more significant in countries with high gender equality.	Future efforts to increase women's participation in STEM include raising awareness and support, inclusive educational environments, changing perceptions and attitudes towards women's abilities, focusing on happiness and life satisfaction, and strengthening. Examples include implementing gender equality policies.

Table 5 Findings and recommendations top cited articles (Indonesia) years (2015-2024).

No.	Cited by	Authors	Source title	Finding	Recommendations
1	239	Sukendro et al. (2020)	Heliyon	Facilitation conditions, ease, and benefits of use influence the use of e-learning among sports science students in Indonesia during the COVID-19 pandemic. The core components of the Technology Acceptance Model (TAM) show significant relationships, except between perceived usefulness and attitude.	1) Better preparation for distance learning by improving technology access, 2) Involve more respondents from diverse backgrounds in future research, and 3) Apply comparative strategies to explore e-learning across different contexts and disciplines.
2	134	Zidny et al. (2020)	Science and Education	Integrating indigenous knowledge in science education can enrich students' learning experiences, increase relevance and interest in science, and support sustainability.	1) Teacher training and Science curriculum development responsive to students' cultural context; 2) Sustainable research to effectively integrate indigenous knowledge in science education.
3	82	Aditomo & Klieme (2020)	International Journal of Science Education	Inquiry-based learning activities supported by active teacher guidance positively relate to student learning outcomes. Meanwhile, unguided inquiry activities tend to have a negative relationship.	1) Development of better measurement tools to assess the quality of teacher guidance in inquiry-based learning; 2) Teacher guidance in improving students' science literacy through integrating guided inquiry activities in learning is essential.
4	71	Maryanti et al. (2022)	Journal of Engineering Science and Technology	There has been a significant increase in publications on the SDGs in science education following the declaration of the SDGs in 2016: increased researcher collaboration and the importance of multi-stakeholder involvement in their implementation.	In the future, the SDGs need to be more deeply integrated into the science education curriculum, SDG-related research should increase, multidisciplinary collaboration should be encouraged, educators should be trained, and bibliometric data should be utilized to identify research trends and areas for improvement.
5	59	Martin (2019)	Asia-Pacific Science Education	1) Lack of science education research publications in Indonesia, 2) Government policies have been introduced to improve international collaboration, and 3) Professional organizations play a role in improving the quality of science education.	In the future, to improve the quality of science education in Indonesia, it is necessary to increase research publications in international journals, encourage international collaboration, strengthen the role of professional organizations, and support government policies.

After the COVID-19 pandemic, the most cited articles (top 5) based on the Scopus database, their findings, and recommendations in science education research are shown in Tables 6 and 7.

After the COVID-19 pandemic, research in the field of science education has increased significantly. Based on the findings and recommendations of the top-cited articles, at the international level (all countries), the trend of post-COVID-19 science education research themes is utilizing digital technology, artificial intelligence (AI), SDGs, adaptive Gamification, and blended learning models. While at the international level (Indonesia), the trending themes are the application of technology, SDGs, Research Evaluation, Virtual Reality (VR), and Augmented Reality (AR). This is in line with research conducted by L.-H. Chen & Nguyen (2024) Demonstrate that the adoption of computational thinking in education has increased significantly, reaching its peak in 2021, indicating a shift towards integrated education strategies and global technological advancements.

Table 6 Findings and recommendations top cited articles (all countries) years (2022-2024).

No.	Cited by	Authors	Source title	Finding	Recommendations
1	465	Cooper (2023)	Journal of Science Education and Technology	ChatGPT can be useful for designing learning units, rubrics, and quizzes in the science classroom, but the results need to be evaluated and adapted to specific teaching contexts.	Going forward, Educators should use ChatGPT responsibly by adapting the generated resources, educating students on the use of AI, and continuing to evaluate its effectiveness in science education.
2	129	Paiva et al. (2022)	ACM Transactions on Computing Education	Automated assessment in computer science education is essential to help evaluate students' programming skills, emphasizing accuracy, efficiency, behaviour, and code readability, while encouraging the development of better tools and methods to support more effective learning.	Create more advanced automated assessment tools, connect to learning management systems (LMS), emphasize conceptual understanding rather than memorizing syntax, analyze student behaviour to provide more personalized feedback, and ensure confidentiality of the assessment process to make it more effective.
3	71	Maryanti et al. (2022)	Journal of Engineering Science and Technology	There has been a significant increase in publications on the SDGs in science education following the declaration of the SDGs in 2016: increased researcher collaboration and the importance of multi-stakeholder involvement in their implementation.	In the future, the SDGs need to be more deeply integrated into the science education curriculum, SDG-related research should increase, multidisciplinary collaboration should be encouraged, educators should be trained, and bibliometric data should be utilized to identify research trends and areas for improvement.
4	71	Zourmpakis et al. (2022)	International Journal of Technology Enhanced Learning	Adaptive gamification in science education increases teacher readiness and motivation, positively impacts teacher and student performance, and identifies practical game elements to increase student engagement and participation.	1) Development of a comprehensive teacher education framework to integrate adaptive gamification into science education, 2) encouraging the use of digital technology, and 3) researching practical game elements
5	69	Finlay et al. (2022)	Journal of Hospitality, Leisure, Sport and Tourism Education	Year 1 and Year 2 students have significant differences in learning experiences. Students preferred blended learning over virtual learning and considered it more supportive of academics, organizations, and learning communities.	1) Develop better-blended learning methods, 2) Improve social interaction in virtual learning, 3) Evaluate and adjust the curriculum to keep the practical experience integrated, and 4) Conduct follow-up research to understand the long-term impact of both learning modes on students' academic outcomes and well-being.

The theme of utilizing digital technology, artificial intelligence (AI), Virtual Reality (VR), and Augmented Reality, the findings and recommendations are expressed by Cooper (2023), Irwanto et al. (2022), and Thohir et al. (2023). Cooper (2023) revealed that ChatGPT can be used to design learning units, rubrics, and quizzes in science education. Although ChatGPT can improve efficiency in the learning process, it still requires evaluation and customization to make its use suitable for teaching needs. Therefore, educators should apply AI wisely, ensuring the content generated is relevant to the learning context. Irwanto et al. (2022) Said publications on AR in science education increased significantly from 2007 to 2022. This trend reflects the importance of AR in enhancing students' learning experience through more immersive interactive simulations. To support this

development, more research is needed on the impact of AR in science learning and training for educators so that this technology can be effectively implemented in the curriculum. Thohir et al. (2023) Said that prospective teachers' acceptance of VR technology is strongly influenced by their understanding of TPACK (Technological Pedagogical Content Knowledge) and the availability of supporting facilities. The main factor determining the success of VR implementation is its ease of use in learning. Therefore, curriculum development by incorporating the latest technology, such as VR, and improving supporting facilities is a good step to increase the effectiveness of technology-based learning in Indonesia.

Table 7 Findings and Recommendations Top Cited Articles (Indonesia) Years (2022-2024).

No.	Cited by	Authors	Source title	Finding	Recommendations
1	71	Maryanti et al. (2022)	Journal of Engineering Science and Technology	There has been a significant increase in publications on the SDGs in science education following the declaration of the SDGs in 2016: increased researcher collaboration and the importance of multi-stakeholder involvement in their implementation.	In the future, the SDGs need to be more deeply integrated into the science education curriculum, SDG-related research should increase, multidisciplinary collaboration should be encouraged, educators should be trained, and bibliometric data should be utilized to identify research trends and areas for improvement.
2	38	Solehuddin et al. (2023)	Journal of Engineering Science and Technology	This study shows a significant growth in the interest and relevance of this topic in science education.	The amount of research in counselling guidance for science education needs to be increased by considering the relevance of new topics and encouraging interdisciplinary collaboration between researchers in education, psychology, and science.
3	36	Kusmaryono et al. (2022)	International Journal of Educational Methodology	This study found that most studies (90%) used odd Likert scales, with 5 points being the most common. Scales of more than five points are more effective in reliability and validity, while even scales are suitable for directing respondents. Response bias can affect the reliability of the scale.	1) Researchers use Likert scales with odd response options to increase reliability and validity, 2) conduct appropriate data analysis according to the data type, and 3) update the literature related to the scale use.
4	23	Irwanto et al. (2022)	International Journal of Emerging Technologies in Learning	The study revealed a significant surge in publications on the use of Augmented Reality (AR) for science education from 2007 to 2022. The United States, Taiwan, and Turkey ranked highest in research contributions. The study also showed strong collaborative networks between researchers from various institutions.	1) increased research on the impact of AR in education, 2) curriculum development that integrates AR, 3) Training for educators, 4) evaluation and continued research to identify best practices in the application of AR in science education.
5	19	Thohir et al., (2023)	Contemporary Educational Technology	TPACK and facility conditions positively influence prospective teachers' acceptance of virtual reality (VR) technology in science education. Ease of use is a key factor influencing the perceived usefulness of VR.	1) increase TPACK training for prospective teachers and improve facilities that support the use of VR, 2) develop curricula that include innovative technologies, 3) conduct further research on technology acceptance factors, and 4) establish partnerships with technology developers to create relevant VR content in science education.

The theme of SDGs, findings, and recommendations was revealed by Maryanti et al. (2022). Implementing the Sustainable Development Goals (SDGs) in science education has also increased since their ratification in 2016. Studies show a surge in the number of publications related to this topic. This indicates the growing attention to sustainability in the education system and the importance of stakeholder engagement to support the implementation of the SDGs in the curriculum. Therefore, in the future, the integration of SDGs in science education needs to be continuously improved. Zourmpakis et al.

(2022) expressed the theme of adaptive Gamification, its findings, and recommendations. Adaptive gamification approaches in science education have improved teacher preparedness and motivation and increased student engagement in the learning process. The study identified game elements that were most effective in increasing student participation, positively impacting their academic outcomes. Therefore, developing a comprehensive educational framework for Gamification to be optimally applied in the education system is necessary. Finlay et al. (2022 expressed the theme of blended learning models, their findings, and recommendations. The findings show that students prefer blended learning to entirely virtual learning. This learning model is considered more supportive regarding academics, learning management, and social interaction. This shows the importance of combining online and face-to-face learning. Kusmaryono et al. (2022) expressed the theme of research evaluation, findings, and recommendations. The study showed that most studies used odd Likert scales, with five-point scales being the most common. Although odd scales are considered more reliable in measuring perceptions, scales of more than five points tend to increase the reliability and validity of research results. Therefore, researchers are expected to consider the type of scale used to produce more accurate data and minimize response bias.

From the explanation above, the development of Science education research does not only include student understanding. However, many other aspects exist, such as the utilization of digital technology, artificial intelligence (AI), Virtual Reality (VR), Augmented Reality (AR), SDGs, adaptive Gamification, and blended learning models. Based on the most cited papers discussed, there are recommendations for each research result. This can be an opportunity for future researchers to develop existing research and examine each paper more thoroughly with new information and open insights, so that they can think more broadly. The current trend in developing science education research is to improve current learning conditions. Thus, it is necessary to adapt media, teaching materials, learning models, and evaluation in science education to post-COVID-19 pandemic conditions.

5. Final Considerations

Based on the discussion results, over the past decade (2015–2024) and post-pandemic (2022–2024), the most productive countries in terms of science education research publications are the United States, followed by the United Kingdom, Germany, and Spain. Indonesia ranks 10th over the past decade and post-COVID-19 pandemic. The number of articles in internationally indexed Scopus publications for all countries showed a consistent increase over the decade (2015–2024) and post-COVID-19 (2022–2024). For Indonesia, the number of published articles experienced a sharp decline during the pandemic (2020) and in the early years after the pandemic (2022). Meanwhile, the Journal of Physics Conference Series was the largest source of science education research publications over the past decade (2015-2024), while after the COVID-19 pandemic, the largest source of science education research publications shifted to AIP Conference Proceedings. The most cited articles across various countries include themes such as the use of digital technology, artificial intelligence (AI), SDGs, adaptive gamification, blended learning models, Virtual Reality (VR), and Augmented Reality (AR). These findings indicate that the COVID-19 pandemic catalyzed the acceleration of the development and implementation of technology in science education research.

Several recommendations can be made for future research development. First, further research with more in-depth analysis of trends in science education research, which continues to undergo innovation, is needed so that findings can be published in international journals. Second, cooperation and collaboration between parties, especially between universities, need to be enhanced to expand the publication network at the global level. Third, continuous research is important to keep pace with the latest trends. Therefore, future research should focus on topics in science education that are relevant to current developments, using appropriate keywords, and involving collaboration with researchers who have expertise in the field of science education.

This study has several limitations that need to be considered, namely that the data used only comes from Scopus-indexed publications used to map post-COVID-19 pandemic trends in science education research. Additionally, documents were selected by searching for the keyword “Science Education” in the “Title” column, covering the periods 2015–2024 and 2022–2024, for all countries and Indonesia.

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Ethical Considerations

Not applicable.

Conflict of Interest

The authors declare no conflict of interest.

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