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# Global Issues and Research Trends on Science Learning: A Bibliometric Analysis

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**Abstract**: Previous research tends to examine science learning in general, but less focus on specific sub-topics, such as inquiry-based learning, project-based learning, or STEAM approaches. The research aims to map the trend of research development related to science learning. There are 987 metadata of Scopus-indexed journal articles from 2019 to 2024. They are analyzed bibliometrically using VOSviewer software combined with the R program and Biblioshiny to find trends in science learning research. The results revealed the development of science learning research from 2019 to 2024. The highest number of Scopus-indexed in 2022 reached 228 publication articles (23.10%). Huwer J's position is the most productive author in science learning research with eight published articles. *Journal of Education Sciences* is the top scientific journal with 56 articles published on the topic of science learning. Michigan State University occupies the first rank as the higher education institution that publishes the most science learning research topics with 36 relevant articles. Science learning research with the topic "education computing, science classroom, engineering education, learning systems, major clinical study, science curriculum, and student motivation" is a cluster of research topics that are still new and potential to be a topic of further research in science learning.

**Keywords***:* bibliometrics, research trends, science learning process.

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## INTRODUCTION

Primary and secondary school science learning plays an important role in shaping students' initial understanding of scientific concepts (Hidayat, 2008; Latipah, 2023). In recent years, research in science learning has grown rapidly. This increase reflects curriculum changes, teaching methods, and learning focus to achieve more holistic educational goals (Noeraida, 2014; Saputra et al., 2019). The concept of learning science for students at school is very important as an initial foundation for learning simple science. With the science learning experience optimally recognized by the teachers, it can form the character of students who care about the environment, are disciplined and responsible, and can think logically and critically in understanding various developments and problems in the surrounding environment (Priyambodo et al., 2022; Susetyarini et al., 2019).

Science learning, in principle, also aims to develop students' competencies so that they can explore and understand the natural world scientifically. Science learning also teaches students how to solve problems, train their understanding skills, draw conclusions, and be objective (Osborne, 2013) (Darmaji et al., 2022). On the other hand, an understanding of research trends is key to directing the improvement of science learning in schools. In this context, the Indonesian government with its innovative education policy has launched a curriculum that emphasizes competency-based learning ((Dwipayanti et al., 2013). As a result, science teachers and researchers at educational institutions have been working hard to adapt learning approaches and strategies to suit the policies of the new curriculum

system in the school environment (Ajeng Arini et al., 2019). This increase creates a profound need to evaluate research trends in the context of the evolving curriculum as it relates to the science learning process for students in the school environment (Santika et al., 2022).

Although there is a lot of ongoing research in science learning, there has not been a thorough analysis of the dominant trends and patterns emerging from the scientific literature related to science learning (Khoeriah et al., 2022; Solikah et al., 2024). Therefore, conducting bibliometric analyses is important to provide a deep understanding of the development of science learning in schools by understanding research trends in terms of the science learning topics studied and the methods used to identify successes, gaps, and potential future research in science learning, especially in the school setting ((Abdul Latip, 2024). The main objective of this article is to conduct a bibliometric analysis of the existing scientific literature on science learning in the school environment.

This bibliometric research aims to identify patterns in existing research, explore trends in research topics, identify key contributors, and highlight areas of research that need more attention (Corrall, 2019; Zupic & Čater, 2015). This research provides not only an overview of science research trends but also valuable insights for educators, researchers, and policymakers in improving the quality of science learning. Mapping research trends in science learning in the school environment through bibliometric analysis is expected to provide teachers with positive implications to formulate more creative and innovative teaching programs, as well as conducting diagnostic assessments of various student difficulties in the science learning process. The construction of this article also aims to provide an in-depth view of the dynamics and development of science learning. A better understanding of the direction of this research can plan more effective and relevant approaches to improving the quality of science learning in the school setting.

Based on the analysis of research trends, it is possible to read the locus of publication of articles and outline the main contributors in relevant academic studies that can be identified. Thus, the process of mapping research trends in science learning through bibliometric analysis can provide an overview of the dominant scientific research issues and those that have not been carried out by many previous researchers related to the development of research in science learning in the school environment. Concerning this, the scope of this article is a bibliometric analysis of research trends in "Science Learning" based on the Scopus database for the period 2019 to 2023. This article has the potential to make a significant contribution to guiding further research development and answering the challenges of science learning. It seeks to describe the mapping of science learning research trends for students in schools including 1) the development of science learning research publications; 2) the productivity of relevant researchers in science learning; 3) the journal of relevant research publications in science learning; affiliations and countries of contributors to science learning research; 4) mapping trends in the development of research topics in science learning. It is expected that this research provides an overview of the development of research related to science learning. The final result of this research description can map research opportunities in science learning at the scope of schools.

## METHOD

This research uses bibliometric methods to map the trend of science learning research sourced from the Scopus database from 2019 to 2024. The research data collection was carried out by searching for Scopus-indexed published articles with the search keywords "science learning" or "science education" based on the search category of article titles, abstracts, and keywords for the last five years. The research data consists of the number of publications per year and journals that contain articles in science learning from 2019 to 2023 with the following keywords:

TITLE-ABS-KEY (Science Learning OR Science Education) AND (LIMIT-TO ( PUBYEAR, 2019 ) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO ( PUBYEAR, 2022 ) OR LIMIT-TO (PUBYEAR, 2023) AND ( LIMIT-TO (EXACTKEYWORD, Science Education) OR LIMIT-TO ( EXACTKEYWORD, Science Learning) AND (LIMIT-TO ( DOCTYPE, ar) ) AND (LIMIT-TO (OA, all ) OR LIMIT-TO (OA, publisherfullgold) AND (LIMIT-TO (SUBJAREA, MULT) OR LIMIT-TO (SUBJAREA, ARTS) OR LIMIT-TO (SUBJAREA, PSYC) OR LIMIT-TO ( SUBJAREA, SOCI) AND ( LIMIT-TO (PUBSTAGE, final).


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Based on the identification of Scopus articles, the metadata of 987 relevant articles that fulfill the criteria were collected. In the next stage, the article metadata was processed and analyzed using bibliometric software. Procedurally, bibliometric analysis included various aspects including frequency of research based on publication year, most productive author, university affiliation, and keywords often appearing in science learning research. The bibliometric analysis process also emphasized topic mapping based on themes often appearing in articles, author, and institution collaboration in relevant research. The bibliometric analysis process is expected to provide an objective perspective on science learning research trends in terms of scientific contributions during the period 2019 to 2023. The use of bibliometric methods is intended to show a scientific approach to understanding the issues and direction of research in the realm of education. Research development, especially in science learning, is expected to make a significant contribution to academics, researchers, and practitioners in understanding and developing the field of science learning in the scope of schools in the education system comprehensively. The bibliometric analysis process related to science learning research trends uses VOSviewer software combined with the help of the R Programme and Biblioshiny. In the context of this research, VOSviewer is software used to visualize bibliometric networks, especially to analyze the relationship among articles, authors, journals, and keywords in scientific literature. Meanwhile, Programme R and Biblioshiny are software programs that are also used for statistical computing and research graphics. Programme R and Biblioshiny are used by researchers for complex data analysis, including bibliometric analysis related to science learning research trends.

## FINDINGS AND DISCUSSION

The content of this article seeks to map the development of research trends in science learning in schools seen from 2019 to 2024 which includes 1) the development of science learning research publications, 2) the productivity of relevant researchers in science learning, 3) journal of relevant publications in science learning research, 4) affiliations and countries of contributors to science learning research, and 5) mapping trends development of research topics in science learning.

### Development of Science Learning Research Publications

The development of science learning research publications for schools based on international publication data from 2019 to 2024 experienced a significant increase when compared to the previous few years. This can be seen in the Scopus-indexed research database, which shows the growth of research publications on science learning was highest in 2022, reaching 228 published articles (23.10%), although there was a decline in 2023 when only 205 articles were published. Further information on publication data on science learning can be seen in Table 1.

**Table 1.** Year Published Science Learning Research

| Year Publication | Document | Percentage (%) |
|---|---|---|
| 2023 | 205 | 20.77% |
| 2022 | 228 | 23.10% |
| 2021 | 212 | 21.48% |
| 2020 | 201 | 20.36% |
| 2019 | 141 | 14.28% |
| Total | 987 | 100 |

The development of research publication growth in the science learning process in schools can be seen in Table 1, and Figure 1 reveals that based on the analysis of the Scopus article database from 2019 to 2022, there was a significant increase in research publications, but in 2023 there was a decrease in publications, reaching 205 publication articles (20.77%). Whereas in the previous two years, or in 2022 there were 228 articles or 23.10%, and in 2021 there were 212 articles or 21.48%. The increase in published science learning research articles was higher when compared to publication data in 2023. Based on the available data, the number of publications increased significantly from 2019 to 2022. In 2019, there were 141 articles published, while in 2022, this number increased to 228 articles. This increase shows a positive trend in researchers' interest and attention to the topic of science learning in


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schools. The decline in 2023 needs to be further analyzed. A variety of reasons, ranging from changes in research focus and post-pandemic impacts to changes in journal policies, could factor into this trend. Therefore, it will be important to understand whether this decline is a temporary fluctuation or an indication of deeper changes in the research landscape of science learning in schools in the coming years.

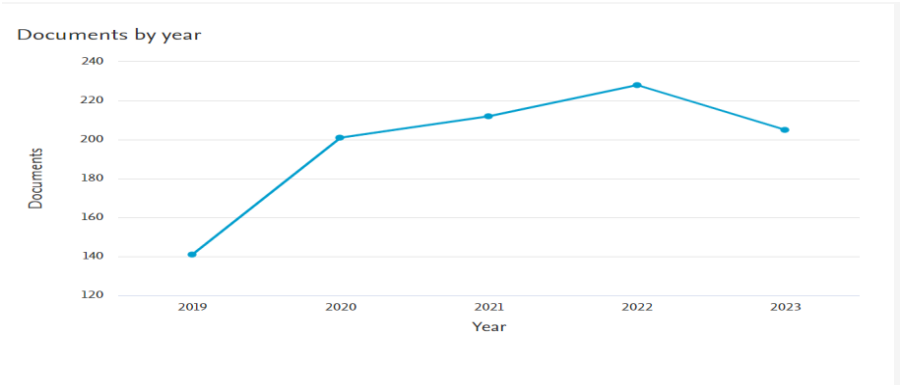


**Figure 1.** Trends in Science Learning Research Publications

## Productivity of Relevant Researchers in Science Learning

The position of research productivity is a hierarchical part of the academic world that can be a source of reference and new knowledge in the development of science learning in the school environment. In general, a researcher with all his scientific productivity, will become the center of information on the sustainability of research for other researchers. It can even be said that the results of the productivity of scientific articles from researchers can encourage innovation and policy in the development of education including in science learning in the school environment. In this context, the description of this article seeks to illustrate the productivity graph of research relevant to science learning funds and how many authors contribute to the number of articles they publish. In general, this graph focuses on the top ten authors with the highest number of publications in the Scopus database that has been analyzed.

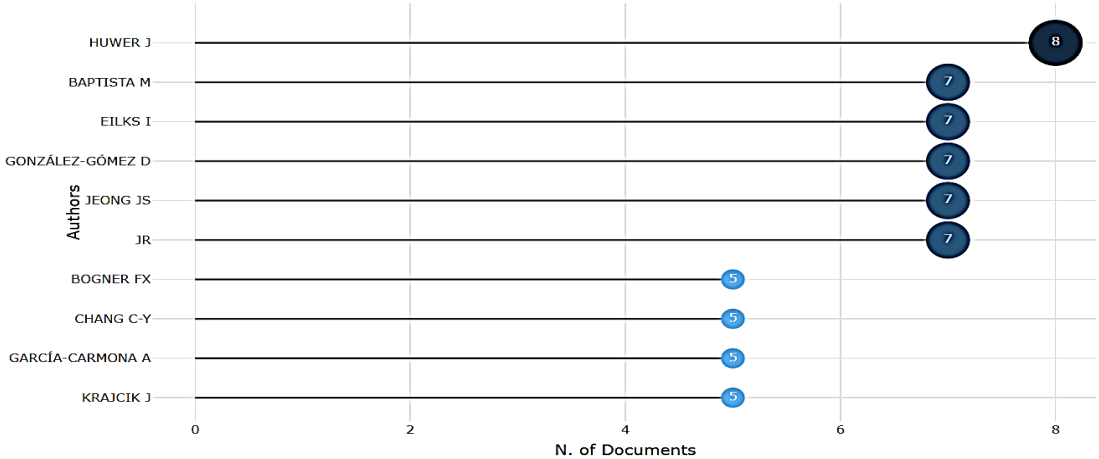


**Figure 2**. The Most Relevant and Productive Author in Science Learning Research

Referring to the graph, we can identify many science learning research articles from the top ten authors in the last five years with the following amount of research article publications: Huwer J with eight articles, Baptista M, Eilks I, González-Gómez D, and Jeong JS with seven articles each; Bogner FX, Chang CY, García-Carmona A, Krajcik J, and Thoms LJ with five research articles each in the Scopus database. In terms of impact factor, the top ten researchers positioned González-Gómez D and Jeong JS as researchers with a fairly high index with H-Index 6 and G-Index 7 respectively regarding the local impact of article publication. The results of the publication of this research article also contribute to the development of knowledge in science learning. This research publication also illustrates


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the dedication and academic commitment of researchers in producing scientific work that is beneficial to the development of science.

**Table 2.** Local Impact of the Author's Publication Results in Science Learning

| Author Name | H-Index | G-Index | M-Index | TC | Years |
|---|---|---|---|---|---|
| González-Gómez D | 6 | 7 | 1.2 | 112 | 2019 |
| Jeong Js | 6 | 7 | 1.2 | 112 | 2019 |
| Andrée M | 4 | 4 | 0.8 | 36 | 2019 |
| Eilks I | 4 | 6 | 0.8 | 40 | 2019 |
| Huwer J | 4 | 6 | 1 | 47 | 2020 |
| Krajcik J | 4 | 5 | 1.333 | 69 | 2021 |
| Sánchez-Martín J | 4 | 4 | 0.8 | 281 | 2019 |
| Vauras M | 4 | 4 | 1 | 32 | 2020 |
| Volet S | 4 | 4 | 1 | 32 | 2020 |
| Zamora-Polo F | 4 | 4 | 0.8 | 281 | 2019 |

***Notes*:**
*H-Index: Citation Index and Number of Author Publications; G-Index: Productivity and Impact of Author Publication*
*M-Index: Impact and Publication Metrics Research Author, and TC: Total Citations of Author's Article Publications*

## Journal of Relevant Publications in Science Learning Research

The source of reference for research publications is important as a dissemination space for authors to publish scientific papers that are relevant to the results of their research, including those related to science learning. In this context, the position of reputable journals can be a resource in accessing various science learning research articles to be used as primary references for researchers in analyzing and examining the development of the main issues of research in science learning. In connection with this, this article will outline a graph of the top ten journals that have published articles related to science learning in the school environment. On the other hand, this graph is also intended to illustrate the contribution of several journals that publish research results in science learning. The description of the top ten journals that are most relevant to the field of science learning is as follows:

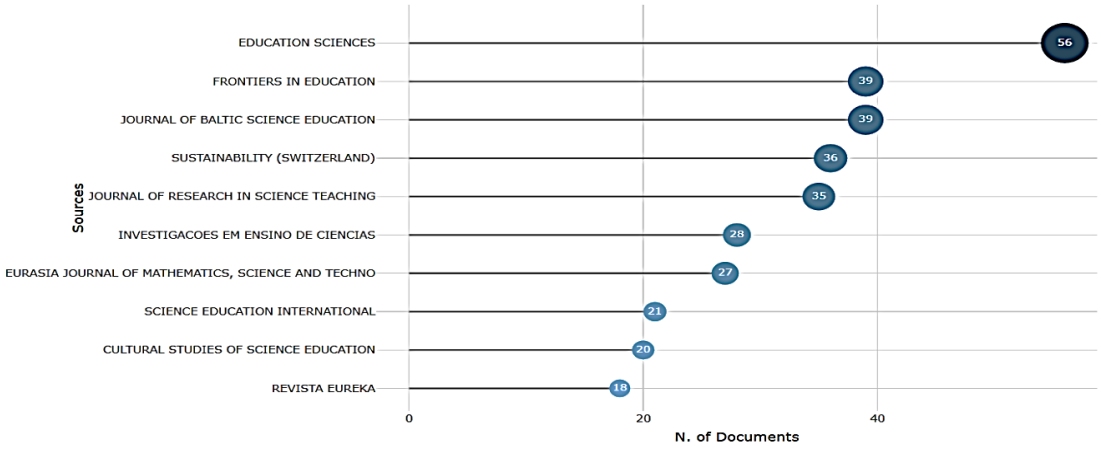


**Figure 3.** The Most Relevant Reputable Journal Source in Science Learning Publications

The graph above shows 10 reputable journals that are most relevant as a publication space in science learning, including *The Journal of Education Sciences*, which is the top journal with 56 articles published, thus positioning this journal as an education journal that makes a significant contribution to the publication of science learning. *The Journal of Baltic Science Education* occupies the second position with 39 published articles that emphasize various innovative research analyses in the field of science education. *The Journal of Frontiers in Education* occupies the third position with 37 articles. This journal is one of the reputable scientific journals that concentrate on the publication of educational


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research. The journal emphasizes the multidisciplinary side that focuses on addressing global education challenges, policies, and practices to provide research-based insights including science learning outcomes. *The Journal of Research in Science Teaching* occupies the fourth position with 35 articles that provide a locus for the publication of scientific research papers from science education researchers and practitioners on issues of science teaching and learning and science education policy.

*The Journal of Sustainability* and *The Journal of Investigacoes Em Ensino De Ciencias* with 33 and 27 articles respectively occupy the fifth and sixth positions as reputable journals that also have a slice of publication of scientific research articles including in the field of science education. The seventh position is occupied by *The Eurasia Journal of Mathematics, Science, and Technology Education* with 26 articles. This journal also focuses on science learning issues such as biology education and astronomy education. The eighth position is occupied by *The Science Education International Journal* with a total publication of 26 articles, which academically focuses on teaching and learning science in school environments ranging from early childhood education to university education. Furthermore, in ninth and tenth places are the journals *Cultural Studies of Science Education* with 21 articles, and *Fibre Journal Revista Eureka* with 20 published articles. These journals are a dissemination space for researchers and practitioners to publish their research results, especially those related to science learning in the school environment.

## Affiliation and Country of Contribution to Science Learning Research

The development of research related to science learning is part of the consistency of researchers affiliated within the scope of educational institutions that academically strive to produce various innovations and critical thinking in conducting various research in the field of education. In this case, the existence of educational institutions, especially at the university level, has an important role in publishing relevant research results including those related to science learning. In addition, the process of developing publications in the scope of educational institutions is also supported by state policy as a major contributor to the development of quality educational institutions, thus affecting the quality of affiliation of institutions/universities in increasing the downstream of scientific publications including those related to science learning research in the scope of educational institutions. In connection with these conditions, this section will describe the top ten affiliates of educational institutions that have academic contributions in publishing scientific articles on science learning research.

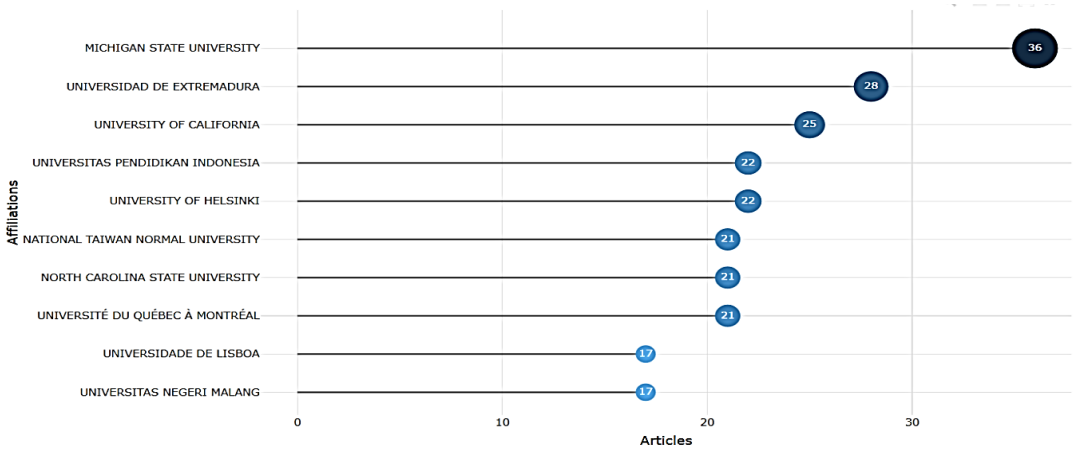


**Figure 4.** Most Relevant and Productive Affiliates in Science Learning Research

The information in Figure 4 above shows a graph of the top ten institutions/affiliates that contribute research and publications in science learning, including Michigan State University, which occupies the first position as the higher education institution that publishes the most research topics related to science learning with 36 relevant articles. Universidad De Extremadura is in the second position with 28 articles of science learning publications. The third place is occupied by the University of California with the publication of 25 articles relevant to science learning. Universitas Pendidikan Indonesia occupies the fourth position with 22 published articles. This university is a higher education institution whose study locus is on national education issues. The University Of Helsinki ranks fifth with


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22 published articles related to science learning. Furthermore, National Taiwan Normal University, North Carolina State University, and Université Du Québec À Montréal occupy the sixth, seventh, and eighth positions as affiliates of higher education institutions that publish research results on science learning with 21 articles each. While Universidade De Lisboa and State University of Malang occupy the ninth and tenth strips with each contributing 17 published articles.

Thus, it can be understood that the position of the top ten affiliates has made a significant academic contribution so that it can be a reference and source of reference for scientific research related to improving the quality of science learning in schools. Furthermore, the results of the analysis also show that some countries with research contributor indices related to science learning are generally still dominated by several developed countries including the top 3 positions occupied by the United States with 209 articles, Spain with 90 articles, and Germany with 79 articles. Australia is positioned fourth with 56 articles, the UK is fifth with 54 articles, and Indonesia is in sixth position with 52 published articles. In the seventh position, Poland contributes 28 articles of publication, the Netherlands is eighth with a total of 20 articles, Switzerland is ninth with 19 articles, and followed by China in the tenth position with 18 published relevant articles, which can be described in the accumulation of the following Table 3.

**Table 3.** Countries Contributing to the Most Productive Science Learning Research

| Country | Documents | Citation |
|---|---|---|
| Australia | 56 | 434 |
| China | 18 | 89 |
| Finland | 28 | 177 |
| Germany | 79 | 680 |
| Indonesia | 52 | 383 |
| Netherlands | 20 | 155 |
| Spain | 90 | 596 |
| Switzerland | 19 | 99 |
| United Kingdom | 54 | 316 |
| United States | 209 | 1788 |

However, when analyzed from the level of productivity of article publications related to the realm of science research in general, the United States is the country with the most contributors with a total of 689 articles that have been published in reputable scientific journals. This condition can be understood due to the bargaining position of the United States for several decades as a center of excellence that pioneered the development of various fields of science, as well as being a center for the development of cutting-edge technology and research in the fields of astronomy, botany, medicine, biology, chemistry, physics, geology and so on. All of these topics of science education are the main focus of the academic studies of higher education institutions in the United States. In the end, the United States also becomes the center of excellence for the development of science and science in the 21st century, as well as positioning the country as a superpower in the progress of various sectors of human life including in the aspect of science learning research as seen from the index of the number of published articles in reputable journals. In connection with this, the following is an overview of the position of the United States as a country with a science research publication index.


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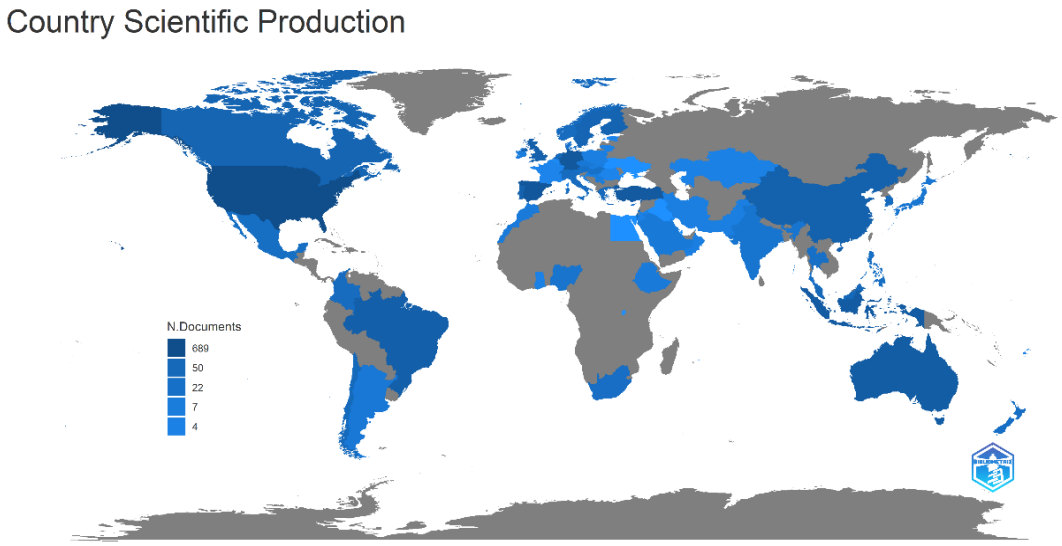


**Figure 5. The** United States is a Major Contributor to Science Research

**Mapping Trends Development of Research Topics in Science Learning**

The development of trends in science learning research topics in the scope of education is something that can be observed, given the increasingly dynamic human behavior and the level of change in various sectors including in the field of education, thus affecting perceptions and approaches to formulate various solutions in solving science learning problems. Even with a change in the educational paradigm, such as curriculum policy and technological advances, the trends become research topics that are analyzed with the assumption that these changes also have an impact on the learning process in the school environment. In this context, the scope of the description of this article seeks to describe the results of the analysis of trends in topics, networks and themes of science learning research identified through keywords from the research database from 2019 to 2024.

**1. Trends in Science Learning Research Topics**

The overview of research topics in science learning at each level of the education unit is the main issue of research that often changes, thus providing space for researchers to examine further, especially on methodologies related to the process of learning science in the school environment. The following will describe the graph of trends in research topics related to science learning in the school environment.

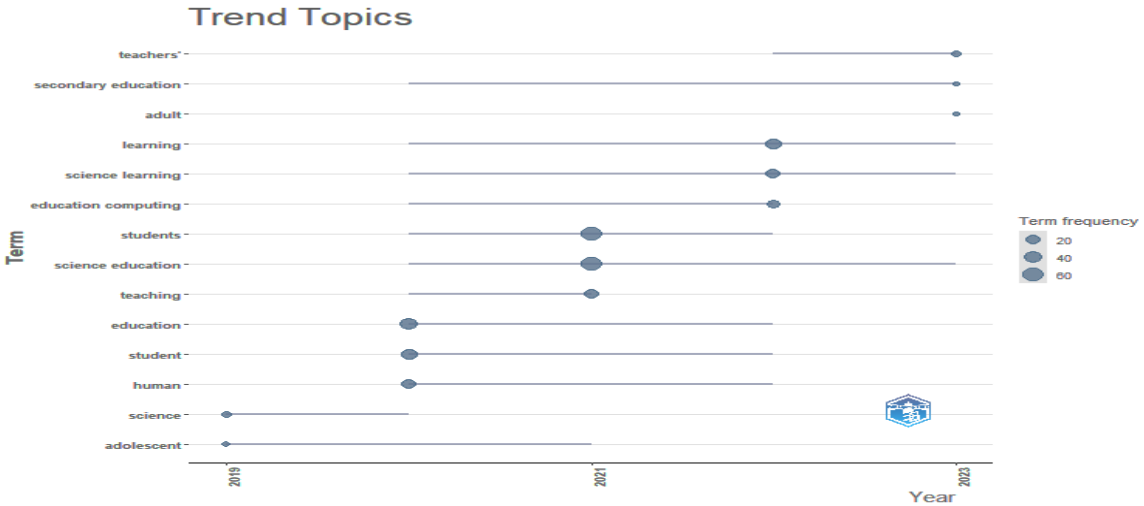


**Figure 6.** Trends in Science Learning Research Topics

Based on the analysis of the graph in Figure 6 above related to the trend of science learning research topics from 2019 to 2023 seen from the frequency of keywords in the Scopus database, several


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relevant topics that are of concern in the research process include the keyword "teachers", which is the main topic category of research that often gets more attention in science learning research. This is based on the fact that science learning is methodologically the responsibility of teachers in planning, implementing, and evaluating science learning activities in the school environment. Teachers in schools are expected to have creativity and innovation in formulating science learning in the school environment and the focus of science research topics tends to be observed from various aspects. The phrase "secondary education" is also a topic that gets attention in science learning research because applicatively the design of science learning is generally studied more holistically at the secondary education level, when compared to the basic education level, so the dominant science research topic describes the results of science learning research at the secondary education level.

Science learning in its implementation at every level can only be carried out optimally by adults, which is reflected in the keyword "adult" which often appears in research publications. The position of adults from a psychological perspective is considered capable of organizing science learning designs in the school environment. In this context, the trend of research topics is also concerned with examining various aspects of adults such as the realm of self-efficacy and epistemic self-efficacy of adults in conducting science learning for students in schools. The keywords "learning and science learning" include keywords that receive attention related to science learning. The frequency of this research topic is closely related to analyzing the scope of the process of science learning activities carried out by teachers in schools ranging from learning approaches, selection of learning models/methods, and the use of science learning media in the school environment.

Trends in science learning research topics in schools can also be seen from the presence of publications related to student issues such as interest in learning, motivation, achievement, and student learning outcomes which are reflected in the keyword "student" which is the topic of science learning research in the school environment. Research topics with the keyword "student" can be said to be the main focus of science learning research in schools because they examine and analyze student development in the process of science learning. The keywords "science education, teaching, and human" are also a massive topic described in the study of science learning research. This keyword domain reflects that the science learning process is attached to various important aspects, including teaching management and human involvement as one of the objects of science education. So the frequency of this research topic is also a significant concern of researchers in conducting scientific research in science learning in the school environment.

## 2. Network Visualization of Science Learning Research Topics

Based on the VOSviewer visualization network circles, there are four clusters consisting of 93 topics related to science learning research. This visual network of topics illustrates the connectivity of research topics that can be done to observe and analyze science learning in the school environment. The four topic clusters can be classified according to the color of each topic that emerges from the visualization results. In this case, the position of the science learning research cluster is represented by red, green, blue, and yellow colors, which are described as follows.

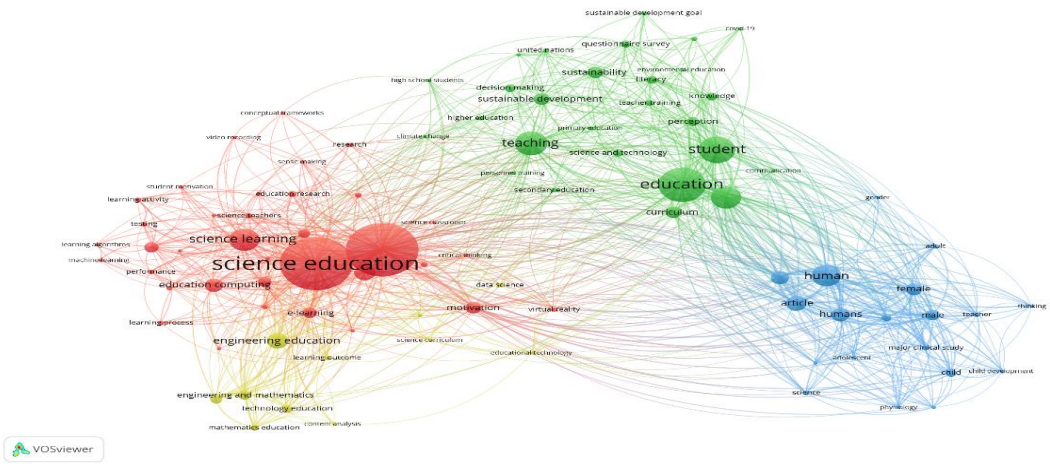


**Figure 7.** Network Visualization Science Research Topics in Science Learning


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The results of the visualization of the mapping of four clusters consisting of 93 topics visualized related to the development of science learning research, as an illustration of the interrelationship of topics that are most likely to be researched and pursued and facilitate the direction of research in seeing the network of relationships between research topics in science learning, which can be described in the following cluster identification table.

**Table 4.** Identification of Science Research Topic Clusters

| Colors | Clusters | Topic Clusters |
|---|---|---|
| Red | Cluster 1 (36 items) | case studies, computer-aided instruction, conceptual frameworks, critical thinking, curricula, e-learning, education computing, experimental groups, informal learning, learn, learning activity, learning algorithms, learning environments, learning process, learning systems, machine-learning, motivation, performance, philosophical aspects, regression analysis, research, science and engineering, science classroom, science education, science learning, science teachers, secondary schools, sense-making, student motivation, students, teachers, testing, textbooks, video recording. and virtual reality. |
| Green | Cluster 2 (27 items) | climate change, communication, COVID-19, curriculum, decision making, education, environmental education, health education, high school students, higher education, knowledge, learning, literacy, perception, personnel training, primary education, questionnaire survey, science and technology, secondary education, student, sustainability, sustainable development, sustainable development goal, teacher training, teaching, united nations, and university sector. |
| Blue | Cluster 3 (19 items) | adolescent, adult, article, child, child development, controlled study, female, gender, human, human experiment, humans, major clinical study, male, psychology, randomized controlled trial, science, teacher, and thinking. |
| Yellow | Cluster 4 (11 items) | content analysis, data science, educational technology, engineering and mathematics, engineering education, learning outcome, mathematics education, middle school students, science curriculum, science technologies, and technology education. |

Based on the graphical and tabular data of the VOSviewer visualization results above, describing a network of science learning research topics from the four-cluster mapping consisting of 93, drawing research topics with the keywords "science education, science learning" being the main topic network that appears and dominates in Cluster 1 in red. In the green-colored Cluster 2, the keywords "teaching, student, and education" are the most emerging topics as the locus of science learning research and have a visual connection with other topics. The keywords "human, major clinical study, psychology" include science research topics that appear the most frequently within the scope of Cluster 3, which is colored blue. In colored yellow Cluster 4, the keywords "engineering education, engineering, and mathematics" are topics that appear quite a lot in science learning research. Based on the data from the visualization of science learning research topics, Cluster 1 focuses on the application of technology in education, especially in science learning. Topics such as computer-aided instruction, e-learning, virtual reality, and machine learning show that research in this cluster is concerned with technological innovations and how they are applied in learning environments. Research in this cluster also highlights concept-based approaches and frameworks to support science learning. Cluster 2 covers topics related to global issues such as climate change, Covid-19, and sustainability. In addition, topics related to environmental education, health, and curriculum development are also the focus here. This cluster incorporates research that links science education to broader global challenges, including sustainable development goals (SDGs) and teacher training to meet these challenges.


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Cluster 3 focuses on psychological aspects and clinic-based studies in science education. Topics such as psychology, gender, and randomized controlled trials mean that this cluster examines how psychological and demographic factors affect science learning. Gender and child development are important themes in understanding differences and disparities in science education. Furthermore, Cluster 4 focuses on the integration of technology in the STEM (science, technology, engineering and maths) education curriculum. Topics such as data science, educational technology, and engineering education show that this cluster examines how technology and STEM education methods can be optimized to improve learning outcomes. Science curriculum is also an important focus, showing attention to developing and evaluating curricula that are relevant to the demands of the times.

The results of the research visualization above also show connections between clusters that are interrelated with research in science learning. *First* is the connection between Cluster 1 (Red Cluster) and Cluster 4 (Yellow Cluster) on technology in learning and STEM curriculum. Application of technology in STEM curriculum: The technologies discussed in Cluster 1, such as virtual reality (VR), e-learning, and machine learning, can be directly applied in the development of the STEM curriculum in Cluster 4. For example, VR can be used in the science curriculum to simulate scientific experiments, so that students can practice science concepts in a safe and controlled environment. The learning technologies discussed in Cluster 1 also relate to how these technologies improve learning outcomes in STEM education in Cluster 4. Research can explore the effectiveness of these technologies in improving students' understanding of science and technology concepts. *Second* is the connection between Cluster 2 (Green Cluster) and Cluster 3 (Blue Cluster) on global issues, psychology, and social change. The effect of global issues on psychology and education: The Covid-19 pandemic (Cluster 2) is a clear example of how global issues affect student psychology and the learning process, which is the focus of Cluster 3. Climate change can also affect students' perception and motivation in learning science, which needs to be understood in the context of learning psychology. In addition, health education in Cluster 2 is linked to how health issues affect student and teacher psychology (Cluster 3). Research can connect how health literacy and education policies during the pandemic affect students' mental health and the effectiveness of the teaching-learning process.

*Third* is the connection between Cluster 1 (Red Cluster) and Cluster 2 (Green Cluster) on the topic of educational technology and global issues. Technology in e-learning and virtual reality topics from Cluster 1 can be used to teach topics in Cluster 2 such as environmental education and sustainability. For example, VR can be used to simulate the impact of climate change, providing students with an immersive experience of the importance of sustainability actions. Global content positioning through e-learning technology in the science research field also enables global access to learning materials related to climate change or sustainable development goals (SDGs). This facilitates a more inclusive and global data-driven education, supporting the global education agenda in Cluster 2.

*Fourth* is the connections between Cluster 3 (Blue Cluster) and Cluster 4 (Yellow Cluster) - psychology and STEM curriculum. Child development and gender from Cluster 3 can affect how the STEM curriculum is designed in Cluster 4. For example, if research shows that boys and girls respond differently to certain teaching methods in science, the STEM curriculum can be adjusted to be more inclusive and effective. The technology used in STEM education in Cluster 4 may have a significant psychological impact on students, especially in terms of motivation, engagement, and confidence. For example, how students respond to technology-based learning can be examined from the perspective of educational psychology described in Cluster 3. *Fifth* is the holistic connections between cluster integration and global impact. The integration of technology from Cluster 1 with a focus on global issues from Cluster 2 creates a more holistic approach to science education. Technology can be a tool to educate students about global challenges and how to deal with them, while the psychological aspects of Cluster 3 can help understand how students respond to these topics in the curriculum covered in Cluster 4. Sustainability-related education (Cluster 2) can utilize educational technology (Cluster 4) to improve learning effectiveness. These technologies can be designed with the psychological aspects of learning (Cluster 3) in mind, such as student motivation and engagement. Thus, the connections between these clusters show dynamic and complementary interactions among different aspects of science learning, ranging from technology, psychology, and global issues, to curriculum development. Research that pays attention to these connections will result in approaches that are more comprehensive and relevant to the challenges of science education in the modern era. It can also open up opportunities for interdisciplinary research that incorporates these various aspects to improve educational effectiveness and inclusiveness.


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### 3. Visualisation of Novelty of Science Learning Research Topics

This section will describe the development of science learning research seen in terms of the novelty of writing articles in Scopus-indexed journals in the last five years from 2019 to 2023.

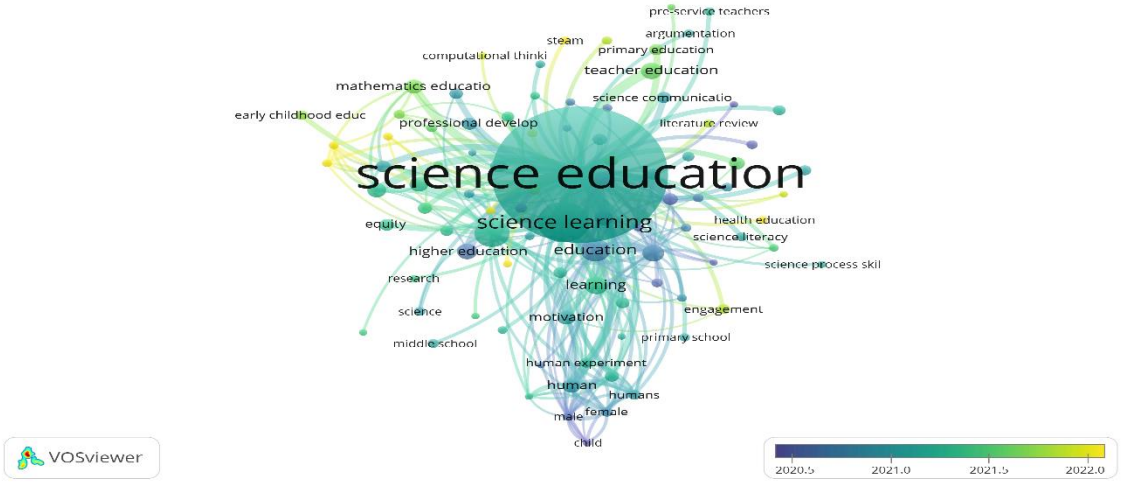


**Figure 8.** Overlay Visualisation of Science Research Topics

The visualization results of the VOSviewer data distribution in Figure 8 show that article writing topics related to science learning are depicted in purple, blue, turquoise, dark green, light green, and yellow. In this case, the topic related to "child development, psychology, and science" in purple is included in the science learning research topic category which has been relatively widely carried out by previous researchers. The topics with the keywords "science learning, computing education, science classroom, and engineering education" in light green are the research topic categories in science learning that have become a research focus in recent years. Meanwhile, research topics with the keywords "learning systems, major clinical study, performance, science curriculum, and student motivation" with the color yellow are a cluster of research topics that are still new and have the opportunity to become research topics. So this topic item can be a reference for the latest research implementation related to the field of science learning in the school environment.

### 4. Visualization of Opportunities for Science Learning Research Topics

The position of research opportunities is a major part of the publication of articles that differentiate and contribute further knowledge in the development of research in science learning. Based on the results of density visualization with VOSviewer, Figure 9 shows the density level of science learning research topics. The density of research topics is shown in bright yellow. The brighter the color of a topic, the more research has been done. On the other hand, the fainter the color, the less researched the topic is or has the opportunity to become a topic that can be developed. The visual depiction of science learning research topics in dim colors includes "science curriculum", "science classroom", "epistemic practices", "student motivation", "science teachers", "virtual reality", “data sciences", "learning processes", "critical thinking", and "learning outcomes" are topics that can be used as references and become research opportunities in science learning, especially in the school environment. This section will describe the research opportunities for science learning that can be carried out further by teachers and academic practitioners in the school environment. The results of the mapping of science learning research opportunities can be a reference for research issues that are relevant and have a level of novelty to be further examined comprehensively, as can be observed in the VOSviewer visualization image in Figure 9 below.


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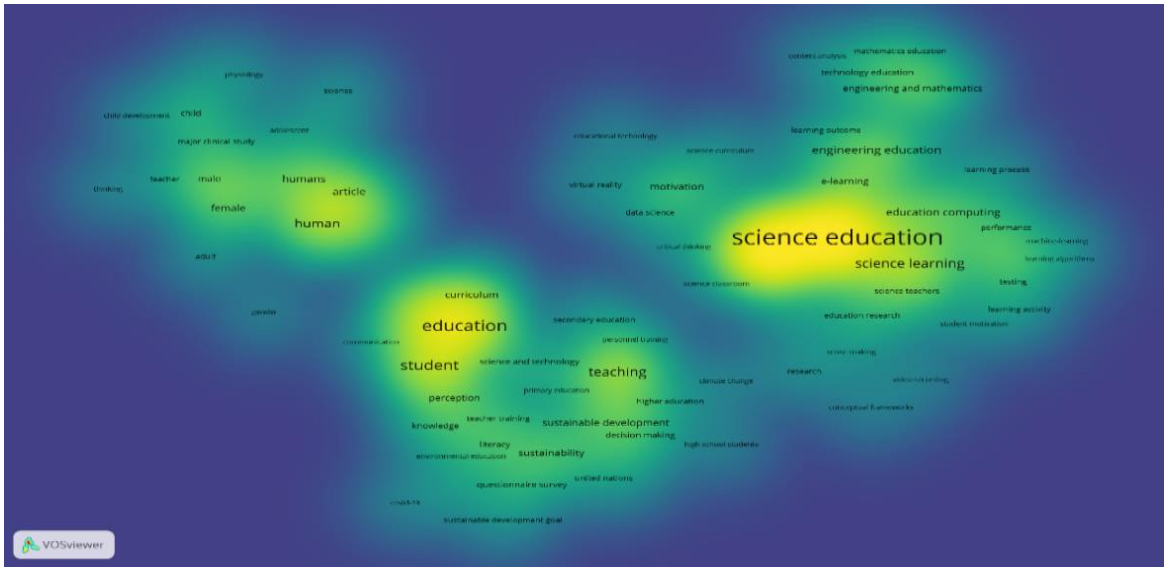


**Figure 9.** Density Visualization Science Research Topics

This thematic mapping provides an overview of research topic trends in science learning from 2019 to 2024. In general, the topics above reflect the focus of researchers and educational practitioners in identifying crucial issues in science learning. The results of this analysis can be used as a reference in developing further research, especially in science learning in the future as an effort to encourage improvements in the quality of science learning services in the school environment. The results of the bibliometric analysis of science learning research trends sourced from the Scopus database from 2019 to 2023 with metadata of 987 articles also provide information and academic mapping that the direction of development of science learning research is considered to be a research issue that is still relevant and interesting for researchers in conducting research seen from topic trends article publication in 2019 to 2023. The results of the analysis of this published article provide an overview of the great research interest in science learning as an approach to forming an understanding of science for students. This condition is in line with several research findings that reflect widespread awareness of the importance of science learning in the education system to encourage scientific abilities and critical thinking in students during the learning process in schools (Megawati, 2018; Dewi, 2019; (Suwastini et al., 2022). So having insight into science learning can encourage innovative academic abilities for students in the future. Apart from this, bibliometric analysis also emphasizes the aspect of topic mapping which most often appears as the main idea of research in written articles (Khoeriah, 2022; (Sumiharsono et al., 2023); (Muna & Bahit, 2023). The findings of this research indicate that science learning research has a technical and methodological scope related to teaching-learning activities carried out by teachers and students as a subject in the school environment which is expected to have an impact on the development of scientific abilities in students. In addition, bibliometric analysis also seeks to reveal a list of leading authors, reputable journal sources, top university affiliations, and countries with major contributors to publications that contribute research and concepts in science learning. However, it is also admitted that the results of this bibliometric analysis still have limitations, especially in terms of article metadata, which only focuses on Scopus-indexed article data. Another limitation is that this bibliometric analysis process examines publication data of science learning articles only from 2019 to 2024 so publication interpretation data from several previous years has not been found. So that it becomes a space and opportunity for further analysis for researchers related to science learning in the school environment.

## CONCLUSION

Based on the results of bibliometric analysis of science learning research trends using metadata from 987 articles in the Scopus database, several main findings are obtained. First, the highest number of science learning research publications occurred in 2022 with 228 articles (23.10%), although there was a decrease in 2023 to 205 articles. Second, Huwer J is the most productive researcher with eight articles, and the *Education Sciences Journal* is one of the top journals with 56 articles related to science


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learning topics. Thirdly, Michigan State University is ranked as the first higher education institution with the most publications related to science learning (36 articles), and the United States is the main contributing country with 202 articles. Fourth, the keywords 'learning' and 'science learning' are the main concerns, especially related to the process of learning science in schools. Fifth, research topics with keywords such as 'education computing', 'science classroom', and 'student motivation' show the potential to be the focus of further research. The results of this study provide academics, researchers, and practitioners with a significant contribution to developing more effective research in science learning in schools. Overall, the results of this study provide researchers and practitioners with important guidance to understand global trends and identify promising research areas in science learning, as well as strengthen the understanding of how global issues affect science education in various contexts.

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