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Cluster Analysis and Network Visualization of Biology Education Research in Indonesia: A Bibliometric Analysis

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Abstract

This study aims to explore the development of BER in Indonesia from 2014-2023 on the Scopus database. Current studies illustrate that the number of publications on biology education has increased in recent years. This trend is likely to continue, as evidenced by the increasing number of publications. A total of 253 papers from the Scopus database were analyzed using VOSviewer software. These findings reveal that BER in Indonesia has grown rapidly in recent years. Zubaidah is the most prolific author, and Universitas Negeri Malang is a leading institution in the progress of BER. The most studied research topics in the last three years are education computing, learning systems, learning processes, and e-learning. The learning topics are plants (botany), animals, biotechnology, and genetics. We also highlight that many topics, such as technology-based learning in biochemistry, algae, and protists, still get less attention. We hope this study can illustrate the current status of BER so that it can help map the direction of future research in Indonesia.

Keywords: Bibliometric Analysis; Biology Education Research (BER); VOSviewer; Scopus

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INTRODUCTION

Biology education is one of the most important aspects of modern education (Susantini et al., 2022). In recent decades, biology education has been significantly transformed to address society's demands for a deeper understanding of nature, ecosystems, and biological phenomena that affect daily life (Aleknavičiūtė et al., 2023). Biological Education Research (BER) has significantly evolved in recent decades reflecting changes in teaching approaches, technology, and understanding of how students learn (Abdullah, 2022; Gul & Sozbilir, 2016).

The large availability of literature on BER makes it necessary to assess these papers using bibliometric analysis to identify their impact and productivity in general. A number of researchers have noted the importance of papers published in journal articles, books, and conference proceedings as they provide relevant information on the progress of scientific research (Fayad et al., 2023). In particular, bibliometric analysis is concerned with a comprehensive assessment of the literature on a subject (Zupic & Čater, 2015). Bibliometric analysis provides valuable statistical and mathematical methods for analyzing the information sources under study (Gronthy et al., 2023). Many bibliometric studies on BER show the growth of literature each year. However, these studies still leave a wide scope in valuing the progress of BER.

A study on the progress of BER has been conducted by Gul & Sozbilir (2015) on 633 papers. The paper discusses the trend of BER in Turkey from 1997 to 2012. The findings indicated that many BERs were conducted in the fields of environment and cell biology. In addition, learning, teaching, and attitudes are frequently researched subjects. This study is based on various documents published by Turkish researchers in all databases, so this study cannot be specific about the progress of BER in specific databases and other regions. Moreover, the study recommends conducting similar research with different samples and appropriate data collection tools to obtain more consistent and comprehensive results.

The same study was also conducted by Abdullah (2022) on 1028 documents. The research discusses research progress, trends, and updates on BER in the Scopus database from 1957 to 2020 globally. The findings indicate that the number of publications on BER has increased in recent years. Evolution, Nature of Science, environmental education, curriculum development, and bioinformatics are the most researched topics. On the other hand, the broad scope of the research conducted provides an overly broad picture of the research topic without explaining in detail its development in each decade.

These studies are largely based on data sourced from Google Scholar and some others sourced from Scopus over a long-time span. In addition, no similar study has attempted to evaluate the progress of BER in Indonesia in the Scopus database using clear bibliometric procedures. In fact, according to Abdullah's findings (2022), Indonesia is the most productive country after the United States regarding BER.

This bibliometric analysis provides a comprehensive overview and explanation of the development of BER in Indonesia that has not been revealed for a decade. This paper is expected to advance biology education research, especially in mapping the development of BER related to research topics and learning topics in Indonesia. Therefore, this study is an effort to fill the research gap related to the progress of BER in Indonesia through bibliometric analysis.

METHOD

The method used in this research is to use the evaluative sciencetometrics method (Sooryamoorthy, 2020). This method is an analytical approach used in bibliometric analysis to measure, analyze, and interpret the progress of research and scientific publications (Donthu et al., 2021). Sciencetometrics allows measuring the impact and significance of scientific publications, identifying research trends, and evaluating the performance of certain researchers and institutions using mathematical and statistical calculations (Donthu et al., 2021).

Search Procedure

In this bibliometric analysis, the procedure used consists of 5 stages adopted from Donthu et al., (2021) &; Muhammad et al., (2022) as shown in Figure 1.

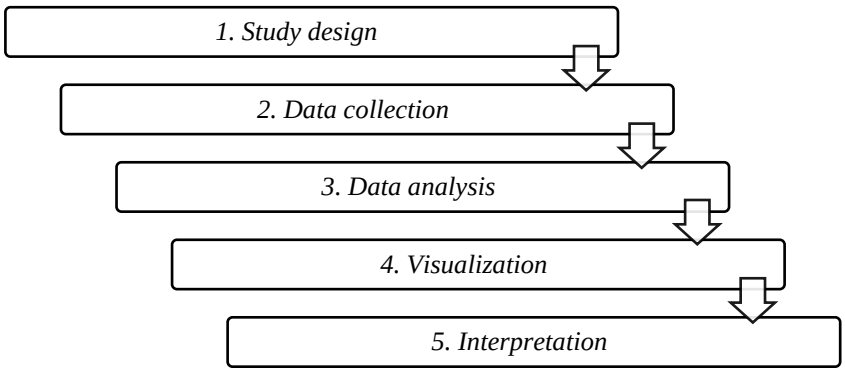

Figure 1. Five Steps Bibliometric Analysis Method

Stage 1: Study design. The study design in this research is based on the main questions adjusted to the research objectives, namely (1) to evaluate the growth pattern of literature related to BER progress in Indonesia from 2014 to 2023, (2) to analyze author co-authorship and institutions based on bibliometric clustering techniques, (3) to find out the most productive institutions and sources based on the number of publications, (4) to find out trending topics based on keyword analysis.

Stage 2: Data collection. This stage is divided into three sub-stages, namely: data collection, data filtering, and data cleaning. Data collection was conducted only on the Scopus database (www.scopus.com) on September 12, 2023. Then, data filtering and data cleaning were performed by censoring titles, abstracts, and keywords, removing materials that were not related to BER, and materials that were not directly related to the research problem. On the other hand, we conducted some preliminary analysis on the Scopus database to collect additional information about authors, affiliations, and journals. The keyword search for this research is: *TITLE-ABS-KEY (Biology Education) OR (Biology Learning) AND PUBYEAR > 2014 AND PUBYEAR < 2024 AND (LIMIT-TO (AFFILCOUNTRY, "Indonesia")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (LANGUAGE, "English")).* Based on those keywords, we found 253 articles that fit the criteria in Table 1.

Table 1. Inclusion and Exclusion Criteria

Inclusion Criteria	Exclusion Criteria
Studies conducted related to BER	The study conducted was not related to BER
Journal articles from the Scopus database	Books, review papers, book chapters, notes, and conference reports
Timespan 2014-2023	Before 2014
Indonesian authors and institutions	Other authors and institutions
Published in English	Other languages

Stage 3: Data analysis. The collected metadata was exported into CSV format for bibliometric analysis with VOSviewer software. The analysis was conducted by viewing co-authorship, co-citation, and co-occurrence. Co-authorship refers to collaboration between two or more authors, institutions, and countries. Co-citation refers to two or more different documents being cited together in another document. While co-occurrence refers to the joint occurrence or co-occurrence of two or more keywords, terms, or topics in publications.

Stage 4: Visualization. Visualization in bibliometric analysis aims to transform complex bibliometric data into more intuitive and informative graphical representations. Visualization helps in identifying relationships between authors, keywords, publications, or topics in the scientific literature. This process allows users to quickly identify collaboration patterns, research trends, and individual contributions to research.

Stage 5: Interpretation. Interpretation in bibliometric analysis is an important step in understanding the results of the analysis. Researchers scrutinize the visualizations, statistics, and findings generated from bibliometric data to identify patterns, trends, and meanings contained in the data. Interpretation involves context analysis, where the researcher tries to explain the emerging patterns and their implications in BER. The results of interpretation are used to inform research progress, identify relevant research areas, and provide a basis for decision-making in the future development of research.

Preventing Selection Bias

In this study, we applied several measures in preventing selection bias. The use of metadata in the Scopus database was chosen because of the wide scope of scientific journal articles and other types of documents, although in this study we only collected information from reputable scientific journal articles. Each keyword, namely "Biology Education" and "Biology Learning" is used because it is closely related to biological research in general. The

interpretation stage is carried out by all authors to overcome misunderstandings of concepts in describing VOSviewer results.

RESULTS AND DISCUSSION

The cumulative publication results of BER development in Indonesia consisted of 253 papers during the period 2014-2023 with an average of 28 papers per year. From those published papers, 183 papers (72.3%) were conference papers, and 80 papers (27.7%) were journal articles. 251 papers (99.2%) were published in English and 2 papers (0.8%) in Bahasa Indonesia. Initially, publications in 2014 and 2015 were the fewest in number with 2 papers (0.8%), then increased by 1 to 3 papers (1.2%) in 2016. In 2017 the number of publications reached 17 papers (6.7%) then increased to 33 papers (13.0%) and 59 papers (23.3%) in 2018 and 2019. 2019 was the highest pinnacle of publications from previous years. In 2020 there was a decrease in the number of publications to 44 papers (17.4%) then increased to 47 papers (18.6%) in 2021. A decrease in publications occurred in 2022 with 18 papers (7.1%) and increased again to 28 papers (11.1%) in 2023 (as of September 12). The value of $r^2 = 0.3681$ shows the consistency value is in the medium category (Chin, 1998). The linear equation has a slope of 4.07 which indicates the average increase in the number of papers each year is about 4 papers.

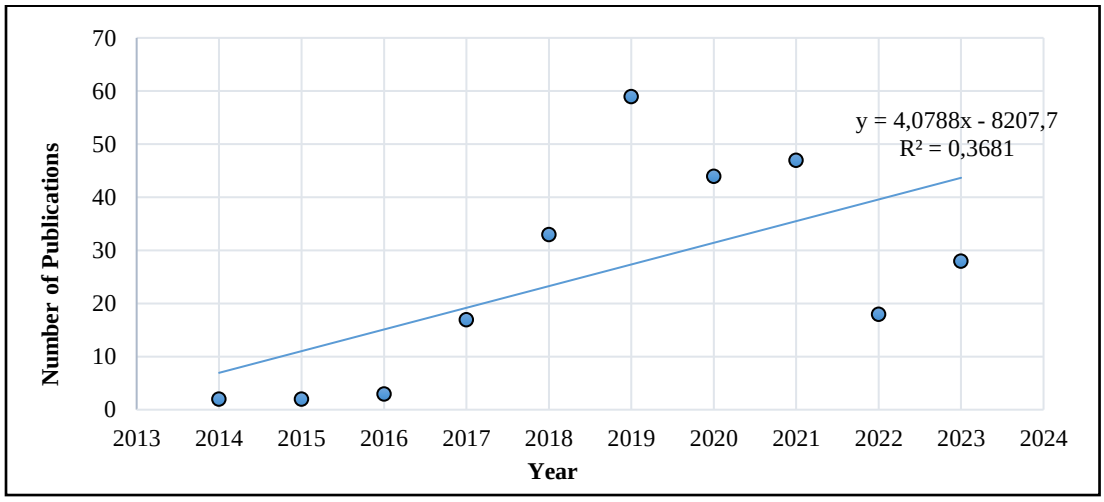

Figure 2. Average Increase in The Number of Papers Each Year

Co-authorship and co-citation analysis

Co-authorship networks are the most common type of collaboration network. The network visualization of authorship in the field of BER is visualized in Figure 3. The circles indicate an author, and the size of the circle represents the number of papers published in the Scopus database. The publication threshold value is set at 4 and 21 authors meet this threshold, which is divided into 3 clusters based on the proximity of the same research topic. Cluster 1 (green color) has 7 authors. Cluster 2 (red color) has 8 authors. Cluster 3 (blue color) has 6 authors. The 10 authors with at least 7 or more collaborating papers are Zubaidah (Universitas Negeri Malang), Mahanal (Universitas Negeri Malang), Rahmat (Universitas Pendidikan Indonesia), Susilo (Universitas Negeri Malang), Redjeki (Universitas Teknologi Digital Indonesia), Suwono (Universitas Negeri Malang), Rustaman (Universitas Pendidikan Indonesia), Corebima (Universitas Negeri Malang), Hidayat (Universitas Pendidikan Indonesia), Riandi (Universitas Pendidikan Indonesia). The strength of the relationship between two or more circles indicates the level of co-authorship frequency between them. The top 10 authors who published 7 or more papers along with their Total Link Strength (TLS), Total Citations (TC), and Number of Publications (NP) are shown in Table 2.

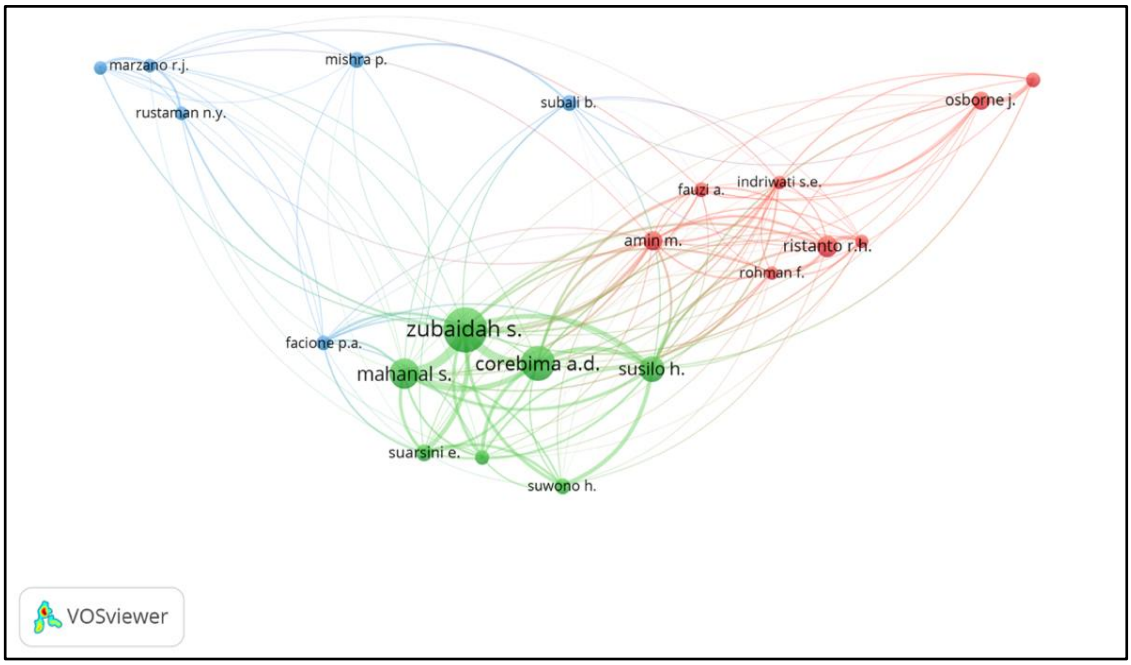

Figure 3. Co-authorship Analysis

Table 2. Top 10 Authors on BER in Indonesia

Rank	Authors	Institutions	NP	TC	TLS
1	Zubaidah, S.	Universitas Negeri Malang	20	122	92
2	Mahanal, S.	Universitas Negeri Malang	13	65	54
3	Rahmat, A.	Universitas Pendidikan Indonesia	13	17	9
4	Susilo, H.	Universitas Negeri Malang	11	50	42
5	Redjeki, S.	Universitas Teknologi Digital Indonesia	10	13	8
6	Suwono, H.	Universitas Negeri Malang	10	21	19
7	Rustaman, N.Y.	Universitas Pendidikan Indonesia	8	16	10
8	Corebima, A.D.	Universitas Negeri Malang	7	79	61
9	Hidayat, T.	Universitas Pendidikan Indonesia	7	17	9
10	Riandi, R.	Universitas Pendidikan Indonesia	7	22	4

The most productive institutions

The top 10 institutions publishing at least 7 papers are included in the list of the most productive institutions in BER in Indonesia from 2014 to 2023. These publications show the contribution of universities in the progress of BER in Indonesia. Universitas Negeri Malang is the institution with the highest number of publications with 52 papers (20.6%), followed by Universitas Pendidikan Indonesia with 44 papers (17.4%), Universitas Negeri Yogyakarta with 19 papers (7.5%), Universitas Sebelas Maret with 14 papers (5.5%), Universitas Negeri Surabaya with 11 papers (4.3%), Universitas Negeri Padang with 9 papers (3.6%), Universitas Muhammadiyah Malang with 8 papers (3.2%), Universitas Sriwijaya with 7 papers (2.8%), Universitas Negeri Jakarta with 7 papers (2.8%), and Universitas Islam Riau with 7 papers (2.8%). The top 10 most productive institutions can be seen in Table 3.

The most productive publishers

The top 10 active sources published 213 papers out of a total of 253 papers related to BER. Journal of Physics Conference Series is the publisher with 106 papers (41.9%), followed by AIP Conference Proceedings with 53 papers (20.9%), International Journal of Instruction with 17 papers (6.7%), Indonesian Science Education Journal with 14 papers (5.3%), IOP Conference Series Earth and Environmental Science with 5 papers (1, 9%), IOP Conference Series Materials Science and Engineering 5 papers (1.9%), Universal Journal of Educational Research 4 papers (1.6%), Education Sciences 3 papers (1.2%), International Journal of

Emerging Technologies in Learning 3 papers (1.2%), Journal of Baltic Science Education 3 papers (1.2%). The top 10 publishers can be seen in Table 4.

Table 3. Top 10 Most Productive Institutions

Rank	Institutions	NP
1	Universitas Negeri Malang	52
2	Universitas Pendidikan Indonesia	44
3	Universitas Negeri Yogyakarta	19
4	Universitas Sebelas Maret	14
5	Universitas Negeri Surabaya	11
6	Universitas Negeri Padang	9
7	Universitas Muhammadiyah Malang	8
8	Universitas Sriwijaya	7
9	Universitas Negeri Jakarta	7
10	Universitas Islam Riau	7

Table 4. Top 10 Most Productive Publishers

Rank	Publishers	NP
1	Journal of Physics Conference Series	106
2	AIP Conference Proceedings	53
3	International Journal of Instruction	17
4	Jurnal Pendidikan IPA Indonesia	14
5	IOP Conference Series Earth and Environmental Science	5
6	IOP Conference Series Materials Science and Engineering	5
7	Universal Journal of Educational Research	4
8	Education Sciences	3
9	International Journal of Emerging Technologies in Learning	3
10	Journal of Baltic Science Education	3

Keywords Analysis

In bibliometric analysis, keyword analysis is the most important part of a study to reflect trends, hotspot areas, and scientific discipline progress (Sooryamoorthy, 2020). The use of VOSviewer can also show the relationship between keywords with each other based on the frequency of occurrence (Donthu et al., 2021). This method uses "association strength" in normalizing the co-occurrence matrix measuring the default values of attraction and repulsion (Donthu et al., 2021). In addition, the grouping of keywords in each cluster is also based on color similarity (Zupic & Čater, 2015).

A total of 928 keywords were obtained in BER in Indonesia. We grouped the keywords into 2 categories consisting of research topics and learning topics. Keywords appearing at least 3 times were selected, and a total of 58 words on research topics and 21 words on learning topics met this threshold. The results obtained are depicted in the keyword network visualization (Figure 4 and Figure 5).

Figure 4 shows the development of research topics in BER over the past 10 years. The map is divided into 5 clusters. Cluster 1 (red) has 23 keywords such as *research and development, education computing, problem-based learning, academic achievements, scientific literacy, scientific reasoning, self-regulated learning,* etc. Cluster 2 (green) has 10 keywords such as *action research, lesson studies, conceptual understanding, critical thinking, distance learning, motivation,* etc. Cluster 3 (blue) has 10 keywords such as *descriptive studies, blended learning, creative thinking, teacher education, STEM, virtual laboratory,* etc. Cluster 4 (yellow) has 8 keywords such as *guided inquiry, technological knowledge, curriculum development, sustainable development, pedagogical knowledge,* etc. Cluster 5 (purple) has 7

keywords such as *cognitive ability*, *HOTs*, *learning strategy*, *metacognitive awareness*, *metacognotives*, *scientific writing*, *and project-based learning*. The top keywords having at least 5 occurrences are in the top 10 list (Table 5).

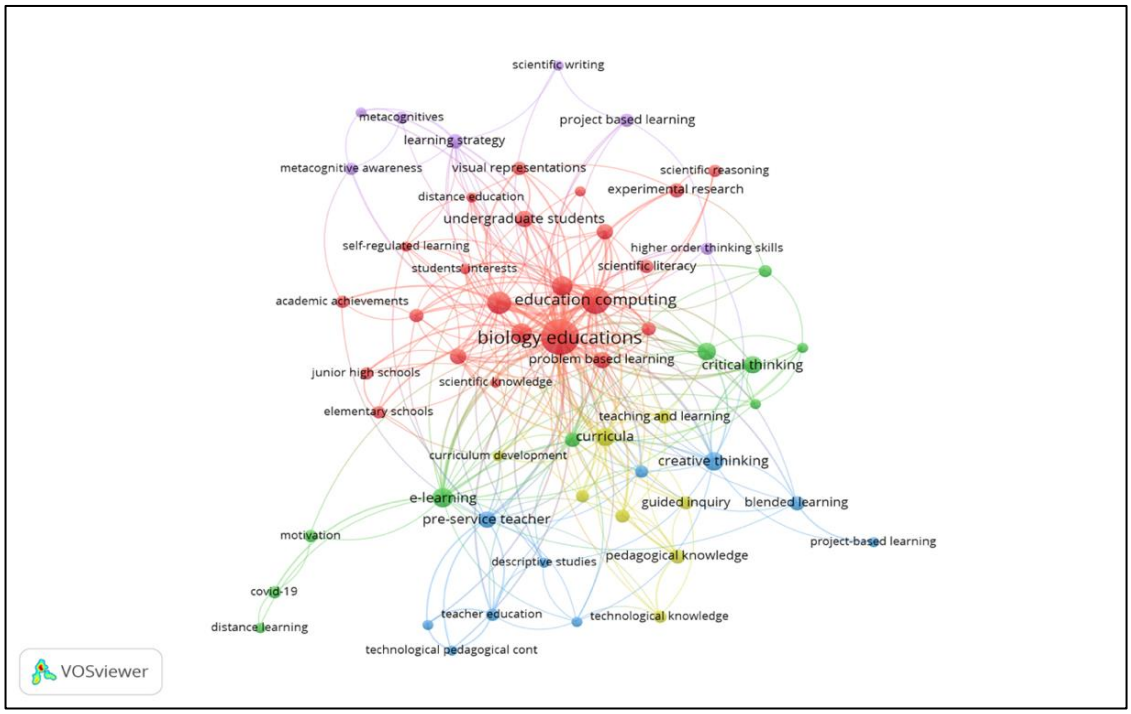

Figure 4. Research Topic Visualization Map in Network Visualization Mode

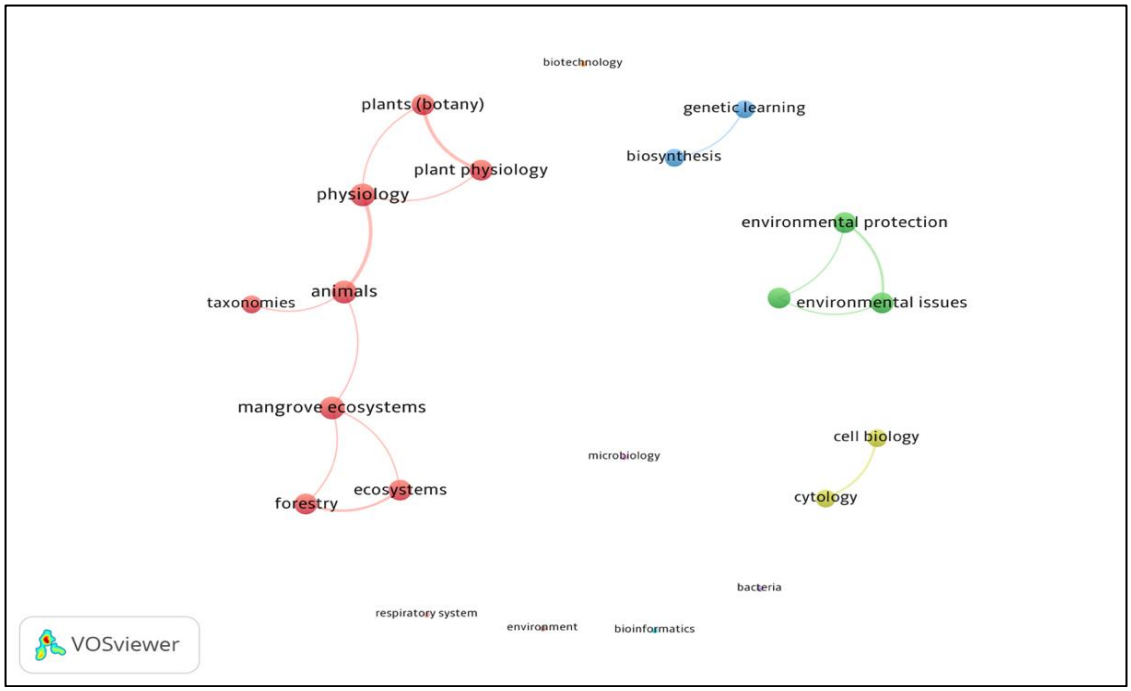

Figure 5. Learning Topic Visualization Map in Network Visualization Mode

Figure 5 shows the progress of learning topics in BER over the past 10 years. The map is divided into 5 clusters. Cluster 1 (red) has 8 keywords such as *Animals*, *Ecosystems*, *Mangrove ecosystems*, *Forestry*, *Physiology*, *Plant physiology*, *Plants (botany)*, and *Taxonomies*. Cluster 2 (green) has 3 keywords such as *Environmental issues*, *Environmental pollution*, and *Environmental protection*. Cluster 3 (blue) has 2 keywords such as *Genetic*

learning and *biosynthesis*. Cluster 4 (yellow) has 2 keywords such as *Cell biology* and *Cytology*. Cluster 5 (purple) has 6 keywords such as *Bacteria, Bioinformatics, Biotechnology, Environment, Microbiology,* and *Respiratory systems.* The top keywords having at least 3 occurrences are in the top 10 list (Table 6).

Table 5. Top 10 Keywords in Research Topics

Rank	Keywords	Frequency	TLS
1	Education computing	41	342
2	Learning systems	16	142
3	Learning process	14	116
4	E-learning	14	108
5	Curricula	12	100
6	Creative thinking	12	57
7	Critical thinking	10	47
8	Pre-service teacher	9	67
9	Problem based learning	8	69
10	Research and development	7	45

Table 6. Top 10 Keywords in Learning Topics

Rank	Keywords	Frequency	TLS
1	Plants (botany)	19	124
2	Animals	8	74
3	Biotechnology	8	49
4	Genetics	6	55
5	Physiology	5	48
6	Cell biology	5	19
7	Microbiology	3	25
8	Bioinformatics	3	24
9	Plant physiology	3	24
10	Ecosystems	3	23

Interpretation of findings

Bibliometric analysis is an effective and efficient measure to summarize and predict research development trends (Su et al., 2022). Based on the analysis obtained, we found various shifts that occurred over the last 10 years related to the progress of BER. Abdullah (2022) stated that in 2020 Universitas Pendidikan Indonesia was the leading institution in BER with 35 documents and then followed by Universitas Negeri Malang with 23 documents. However, the findings changed in 2023, where we found Universitas Negeri Malang leading with 52 documents and Universitas Pendidikan Indonesia with 44 documents. This shift could be due to the different policies and research patterns of each institution.

In addition to the progress of institutions, we also found changes in data related to the most productive authors. Abdullah (2022) tracked that Rahmat was the most productive author with 11 documents and then followed by Redjeki with 10 documents. However, in 2023, Zubaidah and Mahanal were the most productive authors with 20 and 13 documents indexed by Scopus. The data shows that in the last 3 years a significant increase in publications has occurred, despite the fact that the increase occurred only in certain institutions and authors. We assume that the role of collaboration between authors is the main key in increasing the number of publications.

The analysis of keywords related to BER is the main part of this study. Gul & Sozbilir (2015) reported that learning, teaching and attitude/ perception/ self-efficacy were the most studied research topics, while applied practical studies, curriculum studies, teacher training,

concept analysis, test/scale development or translation, general educational problems, research methods studies were less studied. We found that the most studied research topics in 2023 are education computing, learning systems, learning process, and e-learning, while technological knowledge, sustainable development, scientific writing, literacy, technological learning (VR, AR, MR, metaverse), are the least studied research topics. This contrasts with the goals of biology education in the 21st century, namely the mastery of literacy (Semilarski & Laius, 2021; Suwono et al., 2017, 2023) and the use of technology in science (Church, 2020).

We assume that teachers' and students' mastery releted to technology and literacy is still low. Whereas in modern learning the use of technology can facilitate access to information and increase engagement for learning (Domínguez et al., 2021). Various uses of technology in learning such as augmented reality, virtual reality, and interactive learning applications can be used. This is expected to improve the quality of teaching and prepare students with the necessary skills and understanding to face future global challenges (Wu & Ho, 2023).

In addition to tracking research topics, we also looked at learning topics as an essential point in this study. We found that plants (botany), animals, biotechnology, genetics (Table 6) are the most commonly taught learning topics. This is similar to Gul & Sozbilir (2015) who reported that environment, ecology, genetics, biotechnology, animal form and function received great attention in BER progress. This finding proves that there are still many problems in the learning topics taught, so researchers are doing more studies on these topics (Gul & Sozbilir, 2015). On the other hand, we also highlight that there are still many learning topics that get less attention, such as biochemistry, algae, and protists. Whereas these topics are closely related to real life and need to be applied in learning (Andariana et al., 2020; Hardianto et al., 2024; Mahanal et al., 2022).

CONCLUSION

Based on the results of this study, it reveals BER in Indonesia has grown rapidly in recent years. The BER trend over the past 10 years reached its peak in 2019 with 59 papers. Zubaidah is the most productive author and Universitas Negeri Malang is the leading institution in the progress of BER, while the Journal of Physics Conference Series is the publisher with the most publications. The most studied research topics in the last 3 years are education computing, learning systems, learning process, and e-learning. While the learning topics are plants (botany), animals, biotechnology, genetics. We also highlight that there are still many learning topics that get less attention, such as biochemistry, algae, and protists as one of the main topics in more innovative and adaptive learning in the future.

RECOMMENDATION

We hope that this study can illustrate the current status of BER, so that it can help to map the direction of future research in Indonesia. However, this study is still limited in some aspects, specifically only assessing BER trends in the Scopus Database within a decade. It may be advisable to conduct similar research in a different year range and use other databases such as Sinta or WoS, so as to describe the progress of BER more comprehensively. Through further studies, it is expected to discuss research topics and learning topics that have received less attention in BER, such as technology-based learning in biochemistry, algae, and protists.

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