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Secondary Biology Education Research in Southeast Asia (2020 – 2025): A Bibliometric Analysis and Its Implications in Teaching Biology

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Abstract

Research in secondary biology education plays a major role in the development of teaching pedagogies, curriculum alignment, and student learning outcomes. Academic interest in biology education across Southeast Asia has drastically increased recently, with regard to curriculum enhancements, student-centered instructions, and technology-enhanced instruction. However, a systematic mapping of research productivity, thematic directions, and collaboration patterns in Southeast Asia remains limited. Examining these trends may provide valuable insights into regional research themes that are dominant and their implications for biology teaching. This study mapped and analyzed research in secondary biology education in Southeast Asia from 2020 to 2025 using bibliometric analysis. A total of 99 Scopus-indexed publications were analyzed to examine publication trends, leading journals, authors, institutions, and countries, as well as collaboration networks and thematic evolution in the region. Bibliometric indicators and visualization tools, including Biblioshiny and VOSviewer, were utilized to examine research productivity, co-authorship patterns, keyword co-occurrence, and emerging research themes in secondary biology education in Southeast Asia from 2020 to 2025. The findings revealed a noticeable increase in publication output toward the latter years of the period, indicating growing research interest in secondary biology education in the region. Indonesia and the Philippines emerged as the most productive contributors, supported largely by national and university-based journals. Thematic analysis showed that in Southeast Asia, student-centered pedagogical approaches, STEM education, assessment practices, and technology-enhanced biology teaching such as blended learning and digital tools dominate the research landscape. Emerging themes emphasized an increasing focus on inquiry-based learning, critical thinking, and digital pedagogies, while collaboration networks suggest that international research partnerships were limited but gradually expanding. The results reflected Southeast Asia's emphasis on context-responsive and practice-oriented research aligned with ongoing educational reforms. The study concluded by discussing implications for biology teaching, emphasizing the need for evidence-informed instructional practices and stronger research collaboration to further advance secondary biology education in the region.

Keywords: *bibliometric analysis, collaboration networks, secondary biology education, research trends,*

Introduction

Secondary biology education played a vital role in developing students' scientific literacy, strengthening critical skills, giving fundamental knowledge about life sciences and equipping them with attitude for lifelong learning (Wei and Xia, 2016; Santos, 2017; Chengere et al., 2025). Biology education played an essential role in dealing with global issues and provided students

ISSN: 2799 - 1091
Page No. 19-43

scientific proficiency and environmental responsibility (Adnan et al., 2021; Akinwumi, 2023). In line with this, there was an increasing need for innovative pedagogical strategies that connected environmental policy and advocacy in biology education, preparing the future generations to effectively promote sustainable practices (Chen et al., 2024). In the context of Southeast Asia, Biology was a fundamental science subject of the secondary school curriculum across countries such as the Philippines, Indonesia, Malaysia, Thailand, Vietnam, and Singapore. The subject addressed pressing contemporary issues such as biodiversity loss (Coracero et al., 2022), climate change (Chigbu et al., 2021), pollution (Labov et al., 2017) and environmental sustainability (Jufrida et al., 2019). Consequently, studies on pedagogical instruction in secondary biology became increasingly relevant at the secondary level, as such studies played an important role in fostering engaging and effective classroom practices (Azziz et al., 2024; Bhoi, 2024; Manishimwe et al., 2022). Over the past few decades, a consistent increase in published studies related to biology education in Southeast Asia was observed, which showed growing interest in the different aspects of teaching and learning in this field (Abdullah, 2022). However, despite this increasing number of published literature, research studies remained dispersed across various contexts, themes, and journals (Nehm, 2019), which made it difficult for instructors, researchers and policy makers to see the full picture of areas that had been thoroughly studied, as well as emerging trends and significant gaps that needed further exploration (Menard et al., 2024). Previous bibliometric studies illustrated how mapping research fields could identify major authors, institutions, and evolving trends (Aria and Cuccurullo, 2017; Ismai et al., 2025). Nevertheless, several existing reviews and bibliometric studies tended to adopt a broader global scope and gave emphasis on the integration of STEM in the field of higher education (Abdi et al., 2024; Irwanto & Hutahaean, 2025). This left a gap in understanding how secondary biology education research had developed, who the primary contributors were, what dominant themes existed, which areas remained underexplored, and which avenues future studies might take specifically within Southeast Asia. To address this gap, this study aimed to systematically map and analyze research studies on secondary biology education in Southeast Asia from 2020 to 2025 using bibliometric analysis. It examined publication patterns, highlighted prominent authors and journals, and identified key themes and unexplored areas in the field. Thus, the findings were aimed to provide students, biology teachers, teacher educators, curriculum designers, and education policy designers with data-driven findings to support curriculum development, strengthen teacher training, and enhance regional education initiatives (National Science Board, 2021). Through the presentation of an organized map in the research landscape, this study helped minimize repetitive research, guided evidence-based teaching instruction, and strengthened decision-making that improved the quality and relevance of secondary biology education across Southeast Asia.

This study aimed to map and analyze research in secondary biology education in Southeast Asia from 2020 to 2025 using bibliometric analysis, by identifying research trends, gaps, and contributors and interpreting Bibliometric Insights and Implications for teaching in secondary Biology education across Southeast Asia.

Specifically, it answered the following questions:

1. What are the main contributors in terms of journals, countries, institutions and authors in secondary Biology education in Southeast Asia?

ISSN: 2799 - 1091
Page No. 19-43

2. What are the most frequently discussed themes in secondary biology education in Southeast Asia, and how have these themes evolved over time, including the emerging research trends?
3. How has research productivity in secondary biology education developed across Southeast Asian countries over the period 2020 to 2025 in terms of publication output?
4. What gaps can be identified in the existing literature based on the bibliometric analysis?
5. Based on the findings of the study, what are the Bibliometric Insights and Implications for teaching in secondary Biology education across Southeast Asia can be proposed?

Methodology

This study employed a bibliometric research design, a quantitative method used to analyze academic publications. Bibliometric analysis allowed the systematic examination of publication patterns, authorship, institutional affiliations, thematic trends provided both the quantitative and visual representations of in research related to secondary biology education. The study used Bibliometrix R Package to conduct descriptive statistical analysis of the data and VOSviewer to map and visualize network structures using bibliographic data from major databases like Scopus. This study involved identifying appropriate bibliographic data bases, developing search criteria, and selecting analysis software tools to analyse published literature on secondary biology education. Scopus database was utilized and was considered appropriate for the study for it provided credible sources of scholarly publications, offered an extensive multidisciplinary of bibliographic data and its strong emphasis on the peer review process. In addition, it allowed data to be exported directly in formats compatible by common bibliometric analysis tools.

The bibliometric analysis started with extracting data from documents in Scopus. Scopus was chosen as the primary source of bibliographic data due to its comprehensive indexing of author affiliations, citations, and keywords, as well as its capability to export theses data and publication records with various bibliometric analysis tools. After identifying Scopus as the database to be used, the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) (see Figure 1) process was followed.

ISSN: 2799 - 1091
Page No. 19-43

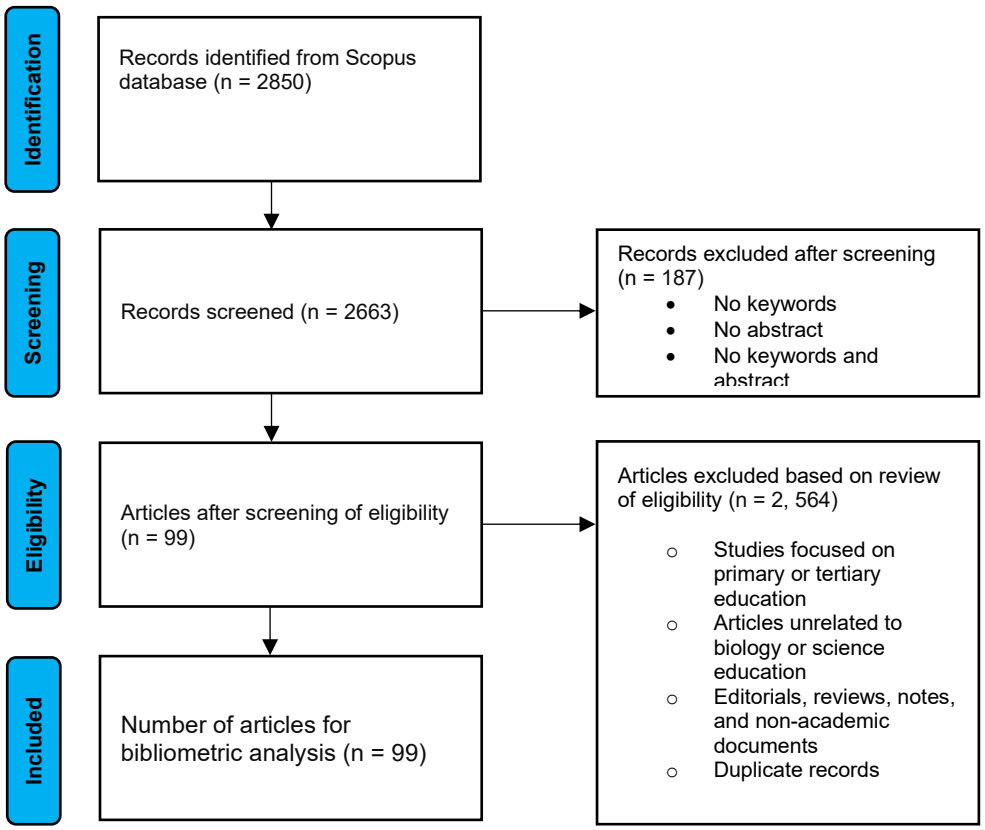


Figure 1. *PRISMA method procedure for identifying and selecting the documents*

ISSN: 2799 - 1091
Page No. 19-43

Table 1

Parameters	Criteria
Database	Scopus
Search String	TITLE-ABS-KEY (("secondary education" OR "high school*" OR "middle school*" OR "junior high*" OR "secondary school*" OR "K-12" OR "grade 7" OR "grade 8" OR "grade 9" OR "grade 10" OR "grade 11" OR "grade 12")) AND (("biology education" OR "biology teaching" OR "biology learning" OR "biology instruction" OR "biology curriculum" OR "science education" OR "life science*" OR "life sciences education" OR "life science* teaching"))
Time Span	2020 – 2025
Subject Area	Limit to: Social Sciences, Psychology, Computer Science, Engineering, Mathematics, Physics and Astronomy, Environmental Science, Chemistry, Agricultural and Biological Sciences
Document Type	Limit to: Article, Conference Paper, Book Chapter
Source Title	All
Publication Stage	Limit to: Final
Keyword	All
Affiliation	All
Funding Sponsor	All
Country/Territory	Southeast Asian Countries
Source Type	Limit to: Journal and Conference Proceeding
Language	English
Open Access	All

Search Strategy and Boolean Search Strings

Initially, relevant keywords were identified based on the focus of the study. The Scopus database was selected as the primary data source due to its wide coverage of peer-reviewed literature and its compatibility with bibliometric analysis tools. Retrieved records were screened using predetermined search queries and inclusion criteria. The selected publications were subsequently analyzed using the Bibliometrix R package through Biblioshiny and VOSviewer to ensure relevance, minimize duplication, and identify patterns and trends in secondary biology education research.

Identification and Screening of Publications

The analysis began with data extraction from documents indexed in the Scopus database. The search strategy was carefully designed to capture literature relevant to the research objectives while minimizing irrelevant results (see Table 1). The query was performed using the TITLE-ABS-KEY field in Scopus, which limited the results to documents containing the search terms in the title, abstract, or author keywords, thereby enhancing conceptual relevance. The search combined terms related to secondary education, such as “secondary education,” “high school*,” “middle school*,” “junior high*,” “secondary school*,” “K–12,” and Grades 7 to 12, with terms

ISSN: 2799 - 1091
Page No. 19-43

related to biology education, including "biology education," "biology teaching," "biology learning," "biology instruction," "biology curriculum," "science education," and "life sciences education." These terms were linked using the Boolean operator AND to identify studies explicitly addressing secondary biology education. Only publications from 2020 to 2025 were included (PUBYEAR > 2019 AND PUBYEAR < 2026).

A set of inclusion and exclusion criteria was applied during the initial screening phase. Only publications classified under relevant subject areas such as social sciences, agricultural and biological sciences, environmental science, psychology, and related interdisciplinary fields were included to ensure alignment with educational research. Document types were restricted to journal articles, conference papers, and book chapters, as these represented peer-reviewed scholarly outputs. Publications were further limited to those written in English and in their final publication stage. The source type was restricted to journals and conference proceedings. In addition, only publications affiliated with Southeast Asian countries were included, while all other regions were excluded. All other search parameters, including source title, keywords, funding information, and open access status, were set to "all." Based on these criteria, 2,850 records were initially identified from the Scopus database. After preliminary filtering, 2,663 records proceeded to the screening stage. Following title, abstract, and keyword screening, publications that focused on higher education, elementary education, non-biology science disciplines, curriculum policy without direct classroom application, or studies not related to teaching and learning processes were excluded. Bibliometric studies, systematic reviews, and meta-analyses were also excluded to maintain focus on empirical and conceptual research outputs relevant to secondary biology education. As a result of this screening process, 187 records were excluded**.**

In the eligibility phase, the remaining publications were independently evaluated by the researcher and an additional reviewer with experience in science education research. The evaluation was based on the titles, abstracts, and author keywords to ensure alignment with the objectives of the study. Any discrepancies in inclusion or exclusion decisions were resolved through discussion until consensus was reached. This validation process was conducted to enhance the reliability and rigor of the article selection procedure. After eligibility assessment and validation, 99 articles met all inclusion criteria and were deemed eligible for bibliometric analysis, consistent with the PRISMA flow diagram.

In the final inclusion phase, the 99 eligible articles were consolidated into a single Microsoft Excel file. Each record contained bibliographic information, including author name(s), publication year, document title, source title, abstract, author keywords, citation count, and country affiliation. This final dataset served as the basis for the bibliometric analysis conducted using Biblioshiny and VOSviewer.

Results and Discussion

This chapter presented, analyzed, and interpreted the bibliometric data gathered from the Scopus-indexed publications on secondary biology education in Southeast Asia from 2020 to 2025. This analysis included the annual publication trends, most productive authors and institutions, leading countries, collaboration patterns, highly cited documents, and dominant research themes in the field. Descriptive statistical analysis and bibliometric mapping techniques generated through Biblioshiny and VOSviewer were employed to illustrate how research in secondary biology education has developed within the specified timeframe (2020-2025). This chapter further

ISSN: 2799 - 1091
Page No. 19-43

included the interpretations of the patterns observed with explanations for its implications in Biology teaching, curriculum development, and potential future directions.

Table 2 presented the general information of documents published from 2020 to 2025 in secondary biology education in Southeast Asia. There were a total number of 99 documents retrieved from 53 sources varying from articles, book chapters and conference paper. With an annual growth rate of 37.97%, the dataset showed a significant increase in research outputs within the given time period. This notable rise showed that secondary biology education had become a growing interest in recent years driven by curriculum reforms, digital and inquiry-based learning strategies and the shift in educational setting.

A total number of 99 documents were indexed in the Scopus database of which 87 were research articles, 11 are conference papers and 1 was a book chapter. The average publication date was relatively recent at 1.68 years. Meanwhile, the average of 3.374 citations per document aligned with the expectations of the literature composed largely of recent studies. Since newer publications require time to generate citations, this means that the impact of citation patterns is in its early stages.

Moreover, 920 references were cited from the 99 analyzed documents, indicating that research in secondary biology education showed a strong engagement with prior research and theoretical foundations within the field. There is a total number of 287 individuals who contributed at least one publication, while 8 authors wrote at least one paper on their own.

Most studies were conducted collaboratively with an average of 3.29 co-authors per document. However, the percentage of international co-authorship is at 13.13% which is relatively low, emphasizing that collaborations in Southeast Asia were mainly contained within national or institutional contexts with limited international engagement. Research on secondary biology education in Southeast Asia from 2020 to 2025 showed a rapid increase, highly diverse, and collaborative, although still limited in international engagements.

Table 2

Main Contributors in terms of journals, countries, institutions, and authors in secondary biology education in Southeast Asia

Variables	Results
General information on articles in secondary biology education research in Southeast Asia	
Data Set Properties	
• Timespan	2020:2025
• Sources (Journals, Books, etc)	53
• Documents	99
• Annual Growth Rate (%)	37.97
• Document Average Age	1.68
• Average citations per document	3.374
• References	920
Document Contents	
• Keywords Plus (ID)	153
• Author's Keywords (DE)	393
Authors	
• Authors	287

ISSN: 2799 - 1091
Page No. 19-43

• Authors of single-authored docs	8
Authors Collaboration	
• Single-authored docs	9
• Co-Authors per Doc	3.29
• International co-authorships (%)	13.13
Document Types	
• article	87
• book chapter	1
• conference paper	11

Table 3

Main contributors in Secondary Biology Education Research in Southeast Asia in terms of journals

Sources	NP	TC	h- index	Q	Publisher	Country
Jurnal Pendidikan Ipa Indonesia	11	37	4	3	Universitas Negeri Semarang	Indonesia
Journal of Biological Education	3	56	3	2	Taylor and Francis Ltd.	United Kingdom
Journal of Turkish Science Education	3	24	3	2		Turkey
Participatory Educational Research	3	25	3	3	Ozgen Korkmaz	Turkey
Biosaintifika	3	4	1	4	Universitas Negeri Semarang	Indonesia
International Journal of Evaluation and Research in Education	3	2	1	3	Institute of Advanced Engineering and Science	Indonesia
International Journal Of Instruction	2	36	2		Gate Association for Teaching and Education	Switzerland
Journal Of Educational Research	2	9	2	1	SAGE Publications Ltd	United States
American Biology Teacher	2	1	1	3	National Association of Biology Teachers, Inc.	United States
Cogent Education	2	12	1	2	Taylor and Francis Ltd.	United Kingdom

Note: NP- Number Published, TC- Total Citation, Q- Quartile based on Scimago Journal Rank (SJR) December 2025

An analysis of main contributors in terms of journal publications on Secondary Biology Education Research in Southeast Asia from 2020 to 2025 based on number of publications (NP), total citations (TC), h-index, journal quartile (Q), publisher, and country of origin. The journal

ISSN: 2799 - 1091
Page No. 19-43

Jurnal Pendidikan IPA Indonesia (JPII) which was published by Universitas Negeri Semarang, Indonesia, produced 11 publications, 37 total citations, and an h-index of 4. JPII served as a key publication venue for secondary biology education research in the region, highlighting Indonesia's significant contribution to regional publications. Its Q3 ranking indicated that the journal was reputable at the national level and commonly published research based on local educational contexts.

In contrast, although the Journal of Biological Education published only 3 articles, it recorded the highest total citations (TC = 56), with an h-index of 3. This indicated that documents published in international journals tended to have greater visibility and citation impact despite lower publication frequency. Similarly, the International Journal of Instruction showed 2 publications and with a high total citation at (TC = 36) revealing strong research influence.

Other journals, such as Journal of Turkish Science Education, Participatory Educational Research and Biosaintifika, which completed the top five sources with significant contributions in the field have contributed 3 publications each. Meanwhile, the remaining five sources, like International Journal of Evaluation and Research in Education, American Biology teacher, and the Cogent Education recorded 3 or fewer publication. Based on the sources' quartile classification, sources published in Southeast Asia were widely spread across Q1 to Q4 journals, which showed its diversity in visibility and impact. Sources such as, the Journal of Biological Education, Journal of Turkish Science Education, International Journal of Instruction, *and* Cogent Education which contributed a lower number of publication but recorded higher citation counts were classified as high impact placing in the Q1 and Q2.

The International Journal of Instruction, did not display quartile rankings due to the absence or variability of SJR data within the exported dataset. In contrast, sources including Jurnal Pendidikan IPA Indonesia, Participatory Educational Research, Biosaintifika, *and the* International Journal of Evaluation and Research in Education were in Q3 and Q4 quartiles indicating their significant role in research productivity within the region.

University based publishers such as Universitas Negeri Semarang which recorded the highest number of publications, highlighted its role in supporting curriculum related research in the region. On the other hand, international publishing houses such as Taylor and Francis Ltd., SAGE Publications Ltd., and the Gate Association for Teaching and Education which published fewer articles but recorded higher citation impact, these showed that while institutional and university-based publishers played a significant role research productivity, commercial and international publishers provided greater global visibility and citation impact.

ISSN: 2799 - 1091
Page No. 19-43

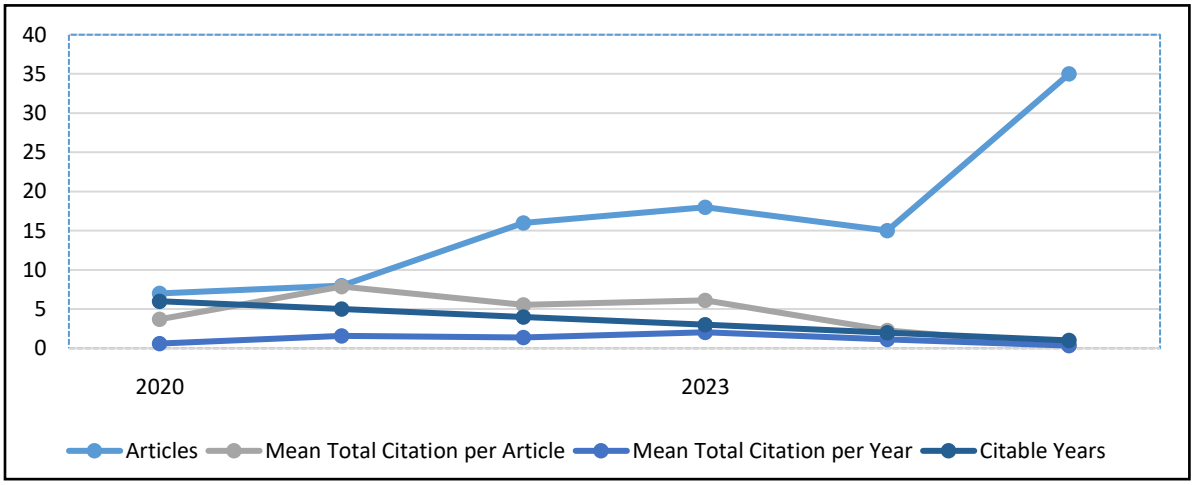
Finally, Indonesia has the highest number of productivity which included Jurnal Pendidikan IPA Indonesia, Biosaintifika, and the International Journal of Evaluation and Research in Education which emphasized the country's strong institutional support for science and biology education research in Southeast Asia. The Journal of Biological Education, Cogent Education, and the International Journal of Instruction, which was published in the United Kingdom and Switzerland, despite recording lower number of publications, has a higher citation performance, which indicated that journals in these countries has a broader international reach and higher research visibility. Meanwhile, source from Turkey and the United States contributed to both regional and global perspectives, supporting cross-country dissemination of secondary biology education research.

Figure 2.

Annual publication trends and citation performance of articles on Secondary Biology Education Research in Southeast Asia

This was also supported by Figure 2, which presented the journal publication trends and citations in secondary biology education research. The number of publications in this field showed an upward trend, with a clear increase in activity in the latter years of the time range. Although there was a slight decline in publications during the initial years, recent years showed an increase in publication activity, indicating growing research interest in secondary biology education within the region.

MAIN CONTRIBUTORS IN SECONDARY BIOLOGY EDUCATION RESEARCH IN SOUTHEAST ASIA IN TERMS OF COUNTRIES



International Journal of Arts, Sciences and Education
Volume 7 Issue 1 | March 2026
ISSN: 2799 - 1091
Page No. 19-43

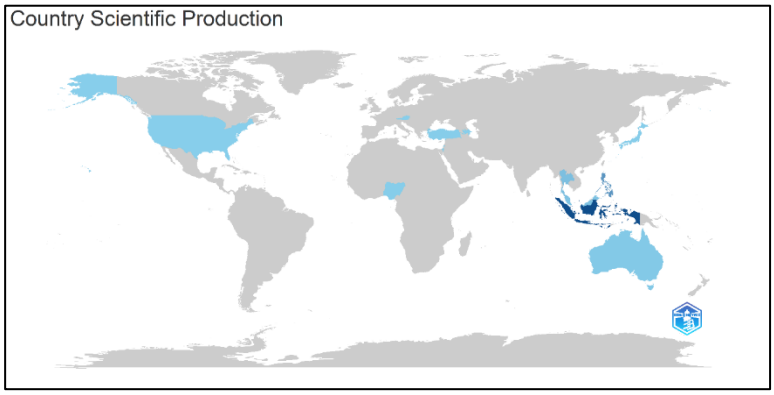


Figure 3.
Scopus document distribution and country collaboration in Secondary Biology Education Research in Southeast Asia

Figure 3 showed the geographical distribution of research output in secondary biology education from 2020 to 2025 based on authors' institutional affiliations. The map used color intensity to represent the number of publications, where darker shades indicated higher research output. This visual presentation supported the numerical data shown in Table 4 which provided a clear picture of both regional and international research participation.

Table 4
Main Contributors Secondary Biology Education Research in Southeast Asia in Terms of Countries

Country	NP	TC	ACPD
Indonesia	102	138	4.10
Philippines	44	43	2.90
Thailand	12	11	1.40
Malaysia	9	5	1.70
Australia	5	8	8.00
Israel	2	0	0.00
Japan	2	2	2.00
Nigeria	2	5	5.00
Singapore	2	0	0.00
Turkey	2	3	3.00

Note. NP – Number Published, TC – Total Citation, ACPD – Average Citation per Document.

Table 4 showed the main contributors in terms of countries in Southeast Asia, recording the highest number of publications based on author affiliations. Indonesia emerged as the leading contributor, with 102 publications and 138 total citations, indicating strong research productivity and active scholarly engagement in the field. Its average citation per document (4.10) suggested moderate research impact, supported largely by national and regional journals. The Philippines ranked second, contributing 44 publications and 43 total citations, reflecting consistent research activity but lower citation impact compared to Indonesia. Thailand and Malaysia showed moderate

ISSN: 2799 - 1091
Page No. 19-43

publication output, with 12 and 9 documents respectively, but with relatively low citation counts and average citations per document. This pattern suggested that these studies were either relatively recent or focused on specific contexts, resulting in limited visibility within the broader research community.

In contrast, Australia demonstrated a high citation impact despite low publication output. With only five publications and an average of 8.00 citations per document, Australian studies appeared to be more influential, likely published in high-impact international journals. Similarly, Nigeria, though contributing only two publications, recorded a relatively high average citation per document (5.00), indicating strong research impact.

Other countries, such as Japan and Turkey, showed contributions with moderate citation performance, while Israel and Singapore recorded no citations, which may be attributed to recent publications or limited dissemination. In general, the findings revealed an uneven distribution of research productivity across countries, with Southeast Asian nations contributing most of the output, while selected non-regional countries demonstrated higher citation impact. This pattern highlighted the need for broader regional participation and stronger international collaboration in secondary biology education research.

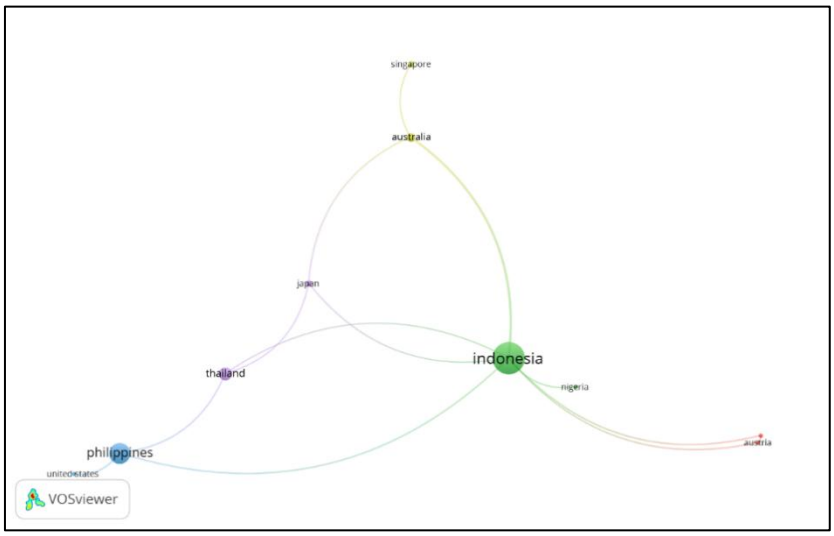


Figure 4.
Co-authorship network among countries on secondary biology education research in Southeast Asia (2020-2025)

Figure 4 illustrated the co-authorship network by countries involved in secondary biology education research in Southeast Asia from 2020 to 2025, which was generated using VOSviewer. Each node represented a country, with the size of the node indicating publication output, while the links between nodes reflected international research collaboration. Thicker links denoted stronger co-authorship relationships.

Indonesia emerged as the most prominent and central node in the network, indicating the highest level of research productivity and international collaboration. It maintained connections to several countries, including Australia, Japan, Thailand, the Philippines, Nigeria, and Austria,

ISSN: 2799 - 1091
Page No. 19-43

which suggested that Indonesian researchers frequently collaborate with both regional and non-regional partners. The Philippines appeared as a secondary contributing country, with visible collaborative links, particularly with the United States and Indonesia. Countries such as Thailand, Japan, Singapore, and Australia were present in the network but showed fewer and weaker links, indicating more limited participation in collaborative research. The co-authorship network revealed that secondary biology education research in Southeast Asia was dominated by Indonesia, which functioned as a central hub for international collaboration. This finding aligned with earlier results showing Indonesia's strong institutional productivity and active author clusters, reinforcing its leading role in regional biology education research.

MAIN CONTRIBUTORS IN SECONDARY BIOLOGY EDUCATION RESEARCH IN SOUTHEAST ASIA IN TERMS OF INSTITUTIONS

Figure 5 presented the institutional collaboration network in secondary biology education research from 2020 to 2025, which was generated using VOSviewer. In this visualization, the nodes represented academic institutions or departments, the node size reflected the extent of research productivity or collaboration, the links indicated co-authorship relationships between institutions, and the colors represented collaboration clusters.

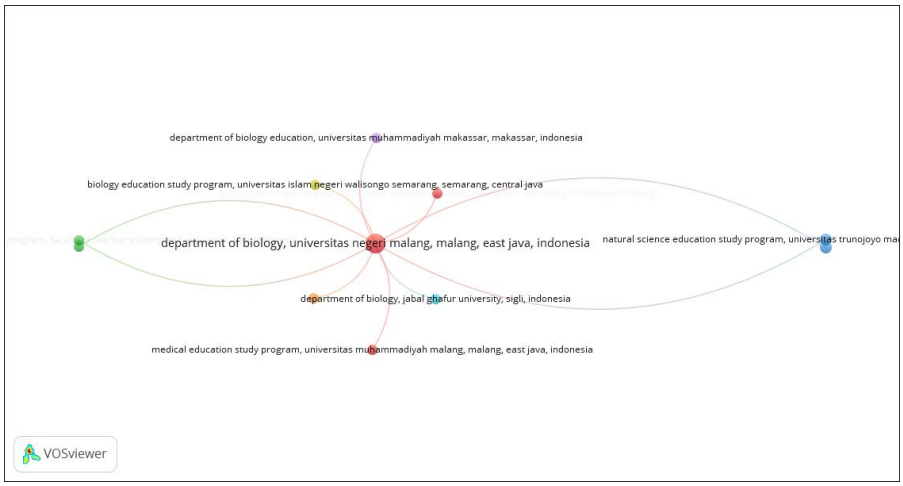


Figure 5.
Co-authorship network among institutions on secondary biology education research in Southeast Asia (2020-2025)

The network revealed a highly centralized collaboration structure, with the Department of Biology, Universitas Negeri Malang (Malang, East Java, Indonesia) which emerged as the primary collaboration center. This institution was positioned at the center of the network and was connected to multiple other institutions, which indicated its dominant role in facilitating inter-institutional research collaboration in secondary biology education. Its central placement and multiple linkages suggested that it served as a key driver of research productivity and partnership formation within the field. Several institutions were directly connected to Universitas Negeri Malang, including the

ISSN: 2799 - 1091
Page No. 19-43

Department of Biology Education, Universitas Muhammadiyah Makassar, the Department of Biology, Jabal Ghafur University, and the Medical Education Study Program, Universitas Muhammadiyah Malang. These connections indicated that collaboration frequently occurred among biology-related departments and education programs, often within similar disciplinary and institutional contexts. Such partnerships suggested a strong orientation toward interdisciplinary collaboration between biology content specialists and education-focused units.

Other institutions, such as the Biology Education Study Program, Universitas Islam Negeri Walisongo Semarang, and the Natural Science Education Study Program, Universitas Trunojoyo Madura, appeared on the network with fewer connections. This suggested limited inter-institutional collaboration, which reflected project-based partnerships or occasional co-authorship rather than sustained collaborative engagement.

MAIN CONTRIBUTORS IN SECONDARY BIOLOGY EDUCATION IN SOUTHEAST ASIA IN TERMS OF AUTHORS

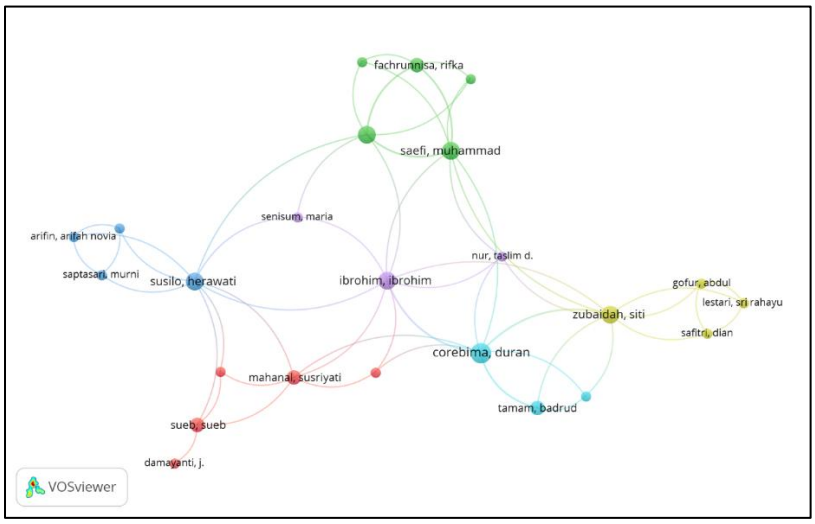


Figure 6.
Co-authorship network among authors on secondary biology education research in Southeast Asia (2020-2025)

Figure 6 illustrated the co-authorship network of authors in secondary biology education research in Southeast Asia from 2020 to 2025, which was generated using VOSviewer. In this network visualization, the nodes represented individual authors, the node size reflected publication productivity, the links indicated co-authorship relationships, and the colors denoted collaboration clusters or groups of authors who frequently published together. The network revealed a moderately collaborative research structure, which was characterized by several distinct clusters connected through a small number of central authors. This pattern suggests that core research teams, rather than a single, highly integrated regional network, largely organize research collaboration in secondary biology education.

Several authors appeared as central nodes, notably Susilo, Herawati, Ibrohim, Saefi, Muhammad, Zubaidah, Siti, and Corebima, Duran. These authors were represented by relatively

ISSN: 2799 - 1091
Page No. 19-43

larger nodes and multiple links that connected different clusters and indicated their influential roles in sustained collaboration across research groups. Their positions suggested that they acted as key contributors and collaboration centers, which facilitated knowledge exchange within and across author groups. Distinct collaboration clusters were also evident in the visualization. For instance, one cluster centers around Susilo, Herawati and Saptasari, Murni, which indicates a closely connected group of collaborators, while another cluster includes Zubaidah, Siti, Gofur, Abdul, Safitri, Dian, and Lestari, Sri Rahayu, which reflected a stable co-authorship group. These clusters suggested that many studies in the field were produced through institution-based or long-term research partnerships.

Despite the presence of several interconnected clusters, the overall network showed a limited cross-cluster integration, with relatively few links which connected distant author groups. This structure aligned with earlier findings which showed a low percentage of international co-authorship (13.13%) and also indicated that most collaborations occurred within national or institutional contexts rather than across countries. Which resulted for the co-authorship field to appear fragmented but stable, with strong collaboration and weaker external linkages.

MOST FREQUENTLY DISCUSSED RESEARCH THEMES AND THEIR EVOLUTION IN SECONDARY BIOLOGY EDUCATION IN SOUTHEAST ASIA (2020–2025)

Figure 7 showed the co-occurrence network of author keywords in secondary biology education research in Southeast Asia from 2020 to 2025 which was generated through VOSviewer. Each node represented an author keyword, with larger nodes indicating more frequent use. Connections between nodes showed how often keywords appeared together, while different colors represented thematic clusters. In this study, identified trends referred to well-established and frequently occurring research themes, while emerging frontiers denoted newer and developing areas that showed increasing prominence in recent years but remained less mature in the literature.

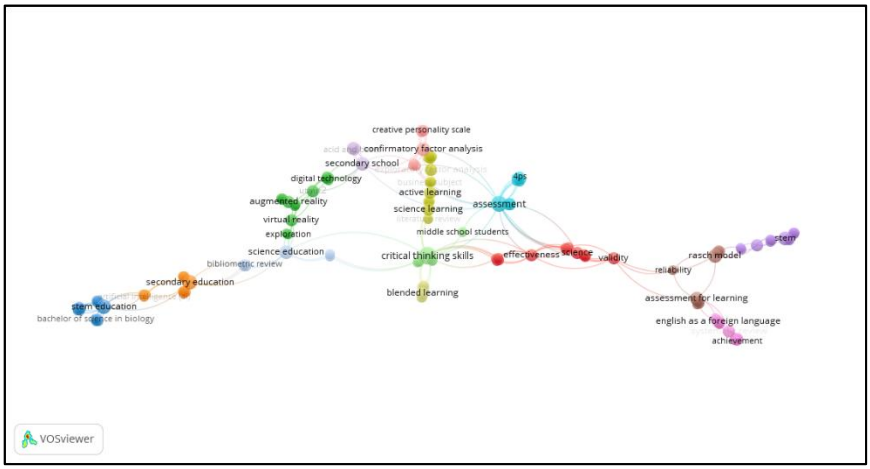


Figure 7.

Keyword Co-occurrence Network of Author Keywords in secondary biology education research in Southeast Asia (2020-2025)

International Journal of Arts, Sciences and Education
Volume 7 Issue 1 | March 2026
ISSN: 2799 - 1091
Page No. 19-43

The visualization revealed several related clusters, which indicated a wide range of research themes. Frequently occurring keywords included science education, secondary education, STEM education, assessment, science learning, critical thinking skills, blended learning, augmented reality, virtual reality, and digital technology. These keywords highlighted the dominant research interests in the field. The co-occurrence patterns indicated that secondary biology education research in Southeast Asia was pedagogically driven, with strong emphasis on active learning approaches, technology integration, and assessment practices. The central position of science education and science learning indicated that biology education research was closely aligned with broader science education frameworks rather than being treated as an isolated discipline.

The prominence of technology-related keywords reflected a regional response to digital transformation in education, particularly in the post-pandemic period. Meanwhile, the strong methodological cluster centered on assessment validity and reliability suggested increasing attention to research rigor and evidence-based evaluation of instructional interventions. However, fewer keywords related to local biological contexts, such as biodiversity or environmental biology specific to Southeast Asia, indicated limited emphasis in context-based biology education research.

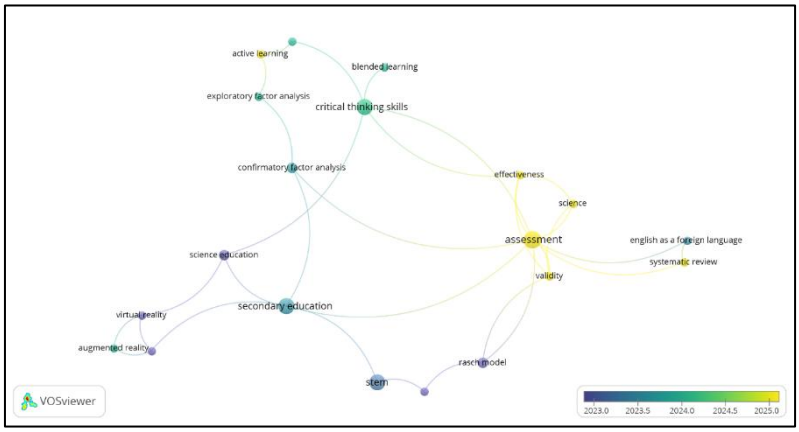


Figure 8.
Visualization of author keyword occurrence over time on secondary biology education in Southeast Asia (2020-2025)

Figure 8 illustrated an overlay visualization of author keyword occurrence over time in secondary biology education research in Southeast Asia from 2020 to 2025, which was generated using VOSviewer. In this visualization, each node represented an author keyword, while the color gradient indicated the average publication year, with darker colors corresponding to earlier years and lighter colors representing more recent research focus.

The findings indicated that studies published between 2020 and 2021 largely emphasized foundational instructional themes, including science education, secondary education, STEM, and emerging educational technologies such as virtual and augmented reality. Keywords that became more prominent during 2022–2023 reflected a shift toward learner-centered pedagogies, which included critical thinking, blended learning, and active learning, along with increased use of statistical techniques for instrument development and validation in secondary biology education.

International Journal of Arts, Sciences and Education
Volume 7 Issue 1 | March 2026
ISSN: 2799 - 1091
Page No. 19-43

More recent keywords, shown in lighter colors and concentrated around 2024–2025, included assessment, validity, Rasch model, effectiveness, systematic review, and English as a foreign language.

The emergence of these terms indicated a growing emphasis on assessment quality, methodological rigor, and evidence synthesis in recent studies. Overall, the visualization revealed a progression of research focus that shifted from technology-enhanced and general instructional themes toward evaluation oriented and methodologically stronger research in the later years of the period.

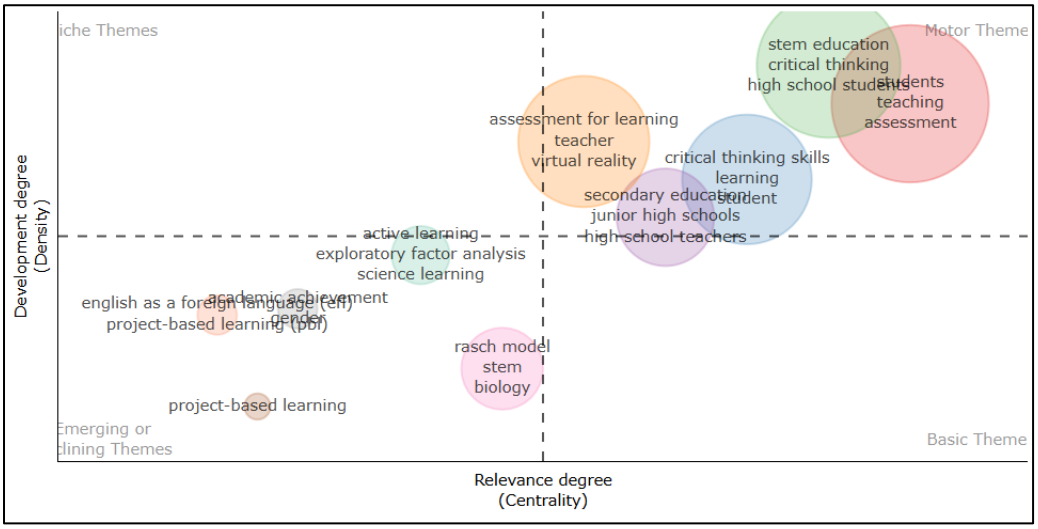


Figure 9.
Thematic Map of Research in Secondary Biology Education research in Southeast Asia (2020–2025)

Figure 9 presented the thematic map of secondary biology education research in Southeast Asia from 2020 to 2025. The map was organized based on relevance (centrality) on the horizontal axis and development (density) on the vertical axis, grouping themes into motor, basic, niche, and emerging or declining themes.

At the core of the map, motor themes such as STEM education, critical thinking, teaching, and assessment appeared in the upper-right quadrant, which indicated that these topics were both highly developed and central to the field. This pattern suggested that current research efforts were strongly directed toward enhanced instructional practices and higher-order thinking skills in secondary biology education.

In contrast, basic themes were located in the lower-right quadrant, which included learning, students, and secondary education, demonstrated high relevance but relatively lower development. These themes served as foundational contexts, that supported a wide range of studies but often functioned as background concepts rather than as primary areas of investigation. Meanwhile, niche themes such as assessment for learning and virtual reality occupied the upper-left quadrant, which reflected strong development but limited integration with other research areas. This indicated that

these topics were specialized and were explored in focused contexts, rather than being widely connected across the broader research field.

Emerging or declining themes, which included project-based learning and advanced measurement models, were in the lower-left quadrant. Their placement suggested that these areas were either still gaining attention or had received limited attention within the field. Taken together, the thematic map revealed that secondary biology education research in Southeast Asia was driven by well-established instructional and assessment-focused themes, while also highlighting opportunities for growth in innovative pedagogies and methodological approaches. These emerging and developing themes, identified through the keyword overlay visualization and the emerging quadrant of the thematic map, represented the emerging research frontiers in secondary

RESEARCH PRODUCTIVITY OF SECONDARY BIOLOGY EDUCATION ACROSS SOUTHEAST ASIA (2020-2025) IN TERMS OF PUBLICATION OUTPUT

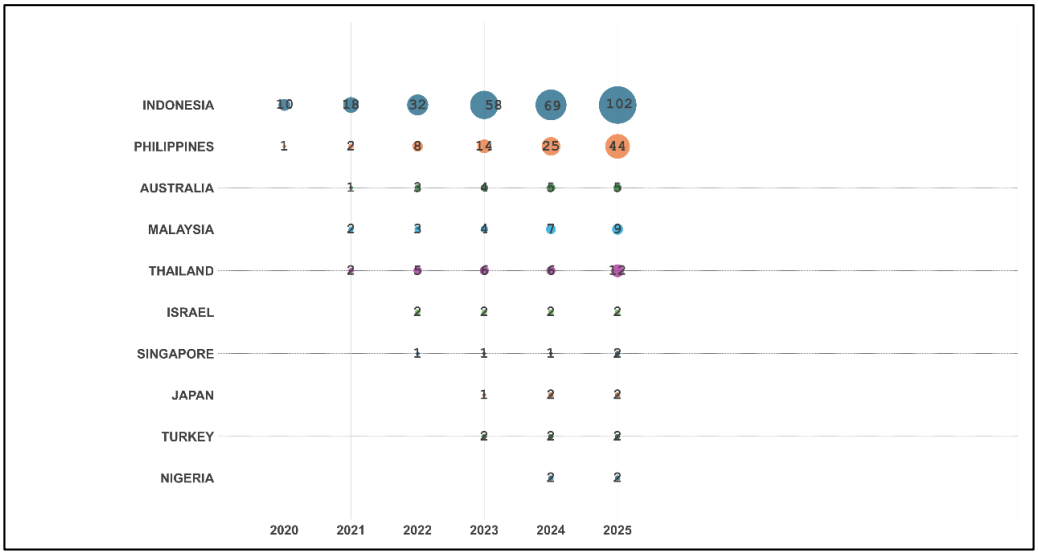


Figure 10.

Matrix Chart of Annual Publication Output of Countries in Secondary Biology Education Research in Southeast Asia (2020-2025)

Figure 10 illustrated the annual Publication Output of Countries in Secondary Biology Education Research in Southeast Asia (2020-2025). The results showed a consistent increase in the number of publications over the six-year period. Overall research output rose steadily from 2020 to 2022, followed by an increase from 2023 to 2025, indicating accelerated publication activity in recent years.

Indonesia recorded the highest number of publications throughout the study period, with output increasing from 10 publications in 2020 to 102 publications in 2025. The Philippines also showed a steady rise in research output, increasing from 1 publication in 2020 to 44 publications in 2025. Other countries displayed lower but gradually increasing publication trends. Thailand's

ISSN: 2799 - 1091
Page No. 19-43

research output increased from no publications in 2020 to 12 publications in 2025, while Malaysia's output rose to 9 publications by 2025. Australia showed an average level of productivity, with publications appearing from 2021 onward and remaining relatively stable through 2025.

Several countries contributed a small number of publications during the later years of the period. Singapore, Japan, Turkey, Israel, and Nigeria each recorded limited publication output, indicating emerging participation in secondary biology education research. Although their contributions were comparatively low, the presence of publications recently reflects expanding research activity across a wider range of countries. These results indicated an increasing trend in research productivity in secondary biology education from 2020 to 2025, with a concentration of publications in a few leading countries and gradual contributions from other countries over time. The inclusion of non–Southeast Asian countries reflected international collaboration and co-authorship patterns, as country attribution in bibliometric analysis was based on author affiliations rather than research location alone.

IDENTIFIED RESEARCH GAPS IN SECONDARY BIOLOGY EDUCATION RESEARCH IN SOUTHEAST ASIA (2020-2025) BASED ON THE BIBLIOMETRIC ANALYSIS

Based on the bibliometric analysis, several research gaps and underexplored areas in secondary biology education in Southeast Asia were identified. Although research output from 2020 to 2025 increased, the distribution of studies across countries remained uneven. A large proportion of publications originated from a small number of countries, while several Southeast Asian nations contributed minimally or were not represented at all. Similar patterns of uneven geographical representation were reported in bibliometric studies of science education research, which highlighted disparities in research capacity and participation across regions (Chkana, et al.,2025; Pham et al., 2023; Zhan et al., 2022).

In terms of research themes, the keyword analysis revealed a strong emphasis on teaching strategies, technology integration, and student learning outcomes. However, fewer studies focused specifically on teacher professional development, classroom assessment practices in biology, and curriculum implementation at the secondary level. Previous bibliometric and review studies indicated that research on teacher professional development in science education remained limited in terms of sustained, context-specific, and practice-oriented models, particularly in developing and diverse educational settings (Amemasor et al., 2025; Ghani et al., 2023; Rosli and Siregar, 2022) .

Likewise, bibliometric mapping of formative assessment research showed that while assessment was widely discussed, there was a lack of empirical classroom-based studies examining teachers' assessment practices and assessment literacy in secondary science education (Saky et al., 2025). Research on curriculum implementation further suggested that investigations on how curriculum reforms were enacted in classroom practice were limited, with many studies focused on challenges rather than systematic implementation of processes and outcomes (Karakuş, 2021). These areas therefore appeared to be underrepresented despite their importance in improving biology teaching and learning.

ISSN: 2799 - 1091
Page No. 19-43

In addition, the collaboration analysis showed limited international and inter-institutional partnerships among researchers in the region. Most studies were produced through national or single-institution, a pattern also observed in other science education bibliometric studies, which indicated opportunities for strengthening cross-country collaboration enhancing knowledge exchange and research quality (Pham et al., 2023).

Emerging topics such as augmented reality, virtual laboratories, and digital learning tools were present in the literature but had low frequency, indicating that these areas were still in the early stages of exploration. Bibliometric analyses of STEM and technology-enhanced education research suggested that while interest in these technologies had increased, empirical evidence on their effectiveness and classroom application remained limited, particularly at the secondary level (Millán and Arango, 2025). Further research was therefore needed to examine the pedagogical value, accessibility, and implementation of these technologies in diverse secondary biology education contexts. Overall, these gaps highlighted the need for more inclusive, collaborative, and practice-oriented research to strengthen secondary biology education across Southeast Asia.

BIBLIOMETRIC INSIGHTS AND IMPLICATIONS FOR TEACHING IN SECONDARY BIOLOGY EDUCATION ACROSS SOUTHEAST ASIA

The findings of the bibliometric analysis suggested several implications for teaching secondary biology education in Southeast Asia. The prominence of student-centered and inquiry-based approaches in the literature indicated a shift toward instructional practices that actively engage learners in the construction of biological knowledge. The findings suggested that biology teachers might have benefited from adopting inquiry-driven, problem-based, and experiential learning strategies to promote deeper understanding of biological concepts. The increased emphasis on technology-enhanced learning highlighted the importance of integrating digital tools, such as virtual laboratories, simulations, augmented reality, and blended learning platforms, into biology instruction. These trends emphasized the need for continuous professional development to support teachers in the effective and pedagogically sound use of educational technologies, particularly when teaching abstract and complex biological processes.

Findings related to assessment practices suggested that effective biology instruction should have been supported by different and formative assessment strategies. Teachers might have benefited from incorporating performance-based assessments, laboratory tasks, and reflective activities to better evaluate students' conceptual understanding, scientific skills, and inquiry processes. Additionally, the uneven distribution of research productivity across Southeast Asian countries and the limited level of international collaboration indicated the importance of contextualizing teaching strategies to diverse classroom settings. Strengthening professional networks and encouraging collaboration among secondary biology educators could have facilitated the sharing of effective, context-responsive instructional practices across the region.

Overall, the results emphasized the need to align secondary biology teaching practices with current research trends while remaining responsive to local educational contexts. Enhancing teacher capacity, promoting innovative instructional strategies, and supporting reflective teaching practices were identified as essential to improving the quality of secondary biology education in Southeast Asia.

ISSN: 2799 - 1091
Page No. 19-43

Conclusion

Based on the findings of the study, it was concluded that research on secondary biology education in Southeast Asia had expanded steadily from 2020 to 2025. However, the productivity of research remained uneven across countries, with scholarly output concentrated in a limited number of contributors. The evolution of research themes indicated a clear shift toward student-centered and technology-enhanced instructional approaches. Despite this progress, gaps remained in terms of geographical representation, thematic balance, methodological depth, and regional collaboration. Addressing these gaps was essential to strengthening the development of secondary biology education research and practice in Southeast Asia.

Therefore, this study successfully mapped and analyzed research in secondary biology education in Southeast Asia from 2020 to 2025 using bibliometric analysis. It identified key contributors, examined research trends and productivity, uncovered research gaps, and interpreted bibliometric insights and implications for teaching across the region.

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