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Trends and coverage of strengthening literacy in biology learning: Systematic literature review of the Scopus database in four decades

H. Husamah[1*], Miza Nina Adlini[2], Lesy Luzyawati[3], Nurdiyah Lestari[4]
[1]Department of Biology Education, Faculty of Teacher Training and Education, Universitas Muhammadiyah Malang, Jl. Raya Tlogomas No. 246, Malang, East Java, 65144, Indonesia
[2]Department of Biology Education, Faculty of Education and Teacher Training, Universitas Islam Negeri Sumatera Utara, Jl. William Iskandar Ps.V Medan Estate, North Sumatera, 20371, Indonesia
[3]Department of Biology Education, Faculty of Teacher Training and Education, Universitas Wiralodra, Jl. Ir. H. Juanda Km. 3 Singaraja Indramayu, West Java, 45213, Indonesia
[4]Department of Biology Education, Faculty of Teacher Training and Education, Universitas Muhammadiyah Kupang, Jl. KH. Ahmad Dahlan, Kupang, East Nusa Tenggara, 85111, Indonesia
*corresponding author: usya_bio@umm.ac.id

ABSTRACT

This study aimed to analyze the trend and scope of strengthening literacy in biology learning over four decades that will make a valuable contribution to the biology learning in all educational levels. This study employed a systematic literature review (SLR) method adapted from the PRISMA model. This SLR obtained several interesting findings. It was found that the theme of biology and literacy reached its peak in 2023. We found two main countries to focus on, namely the United States and Indonesia. Biology and its learning are synonymous with scientific/science literacy. Other types of literacy that are widely promoted by researchers are information literacy, quantitative literacy, health literacy, visual literacy, computer literacy, three-dimensional literacy, reading literacy, media literacy, assessment literacy, epigenetic literacy, digital literacy, and environmental literacy. In the Indonesian context, we suggest that biology learning needs to be oriented towards strengthening the literacy aspects-science literacy, information literacy, quantitative literacy, health literacy, visual literacy, computer literacy, three-dimensional literacy, reading literacy, media literacy, assessment literacy, epigenetic literacy, digital literacy, and environmental literacy-found in SLR because each of them has an urgency.

Keywords: Biology, Indonesia, literacy, PRISMA, Scopus

INTRODUCTION

Based on data searches on articles indexed in the Scopus database, literacy was first introduced by Fairchild (1917) and then followed by two other experts a few years later (Bloch, 1920; Pressey & Shively, 1919). The term literacy has now become a topic that is widely discussed, regarding human abilities in living life (National Literacy Trust, 2023). Definitions and types of literacy have evolved, no longer having a single meaning but rather multiliteracies (Pilgrim & Martinez, 2013; Walsh, 2017). Literacy describes an individual's ability to identify, understand, interpret, create, communicate and compute content through various media, for the purposes of communication and expression (Montoya, 2018).

Literacy is also related to biology and its learning. Literacy influences a person's understanding and view of biology and its role in society (Bórquez-Sánchez, 2024). When students write practical reports, read various reference books, and analyze scientific articles, of course they must have literacy skills to be successful in science/biology classes. (Mellen, 2021). Semilarski and Laius (2021) have even formulated biological literacy which consists of six dimensions, namely cognitive, affective dimension, sustainability; interdisciplinarity, career awareness, and the nature of biology

The relationship between biology and literacy is interesting to study. The interest of

experts in the world in these two things - which is shown by the track record of their publications - needs to be studied. In this regard, a very possible step is to analyze the articles in the Scopus database - as a representation of the world's largest reputable database (Baas et al., 2020; Guerrero-Bote et al., 2020; Gusenbauer, 2022; Stahlschmidt & Stephen, 2020). One of the most recommended techniques for study and analysis is Systematic Literature Review (SLR).

We tried searching the Scopus database with the phrase "biology+literacy" with search within "all fields". The results show that there are 48,160 documents found. This number is certainly very large and the search is not specific. Therefore, we chose to search within “article, abstract, keywords” which showed results of 1,058 documents found. To make it easier and more focused in the analysis, we focused on searching within "article title" where the number of articles found was 101 (article status is 1987-2024). It can be seen that the article with the theme biology and literacy was written by Ewing et al (1987), 17 years from the first article linking biology and literacy by Lee (1971).

Systematic literature reviews about biology and literacy are still very rare. In the Scopus database, there are only five review articles (not SLR), spanning four decades. The five articles are reviews of experts/researchers, who focus their studies on the relationship between biology and several types of literacy, such as conservation literacy (Trombulak et al., 2004), Information literacy (Ferguson et al., 2006; Porter, 2005), visual-spatial literacy (Milner-Bolotin & Nashon, 2012) and scientific literacy (Mulbar & Bahri, 2021). Thus, it can be said that no SLR has been found that focuses on biology dan literacy.

Therefore, this study aimed to analyze the trend and scope of strengthening literacy in biology learning over four decades. It is hoped that this SLR will contribute in three ways, namely (1) helping to comprehensively identify and summarize existing research findings over four decades, thereby enabling researchers to understand developments (trends) and study directions (coverage); (2) through systematic analysis, this SLR can reveal research gaps, providing a basis for future studies that are more focused and relevant; (3) The results of this SLR may serve as a credible resource for educators (biology teachers and lecturers), policy makers, and academics in designing curricula and intervention programs to effectively integrate literacy with biology learning. Thus, this SLR certainly not only contributes to enriching theoretical knowledge, but also has significant practical implications for improving the quality of education and literacy in the field of biology. Curricula in various countries, including Indonesia, have been focused or oriented towards literacy development, also in relation to responding to the problem of the COVID-19 pandemic. In this regard, in response to existing developments and policies, there has been a lot of research with various types of approaches, focuses and topics, so the impact needs to be studied, which aspects are strong and which aspects are still weak, so that this can be taken into consideration in the future.

METHOD

This investigation constitutes a SLR to systematically identify, assess, and analyze all specific research inquiries, topics, or areas (Chigbu et al., 2023; M. Newman & Gough, 2020). A SLR is a form of review that employs a methodical approach to present a reliable synthesis of current literature focused on a distinct and well-defined inquiry (Moosapour et al., 2021). A SLR play a crucial role in enhancing our understanding of a particular subject matter by revealing both the known information and the gaps in knowledge, frequently surpassing the insights derived from individual research studies (Owens, 2021).

The Research Question (RQ) is what are the trends and scope of strengthening literacy in biology learning in the last four decades? This aspect of the trend is year, and country; refers to

various previous SLRs (Husamah et al., 2024; Nurwidodo et al., 2023). The scope outlines the types of literacy associated with biology learning that are the focus of researchers.

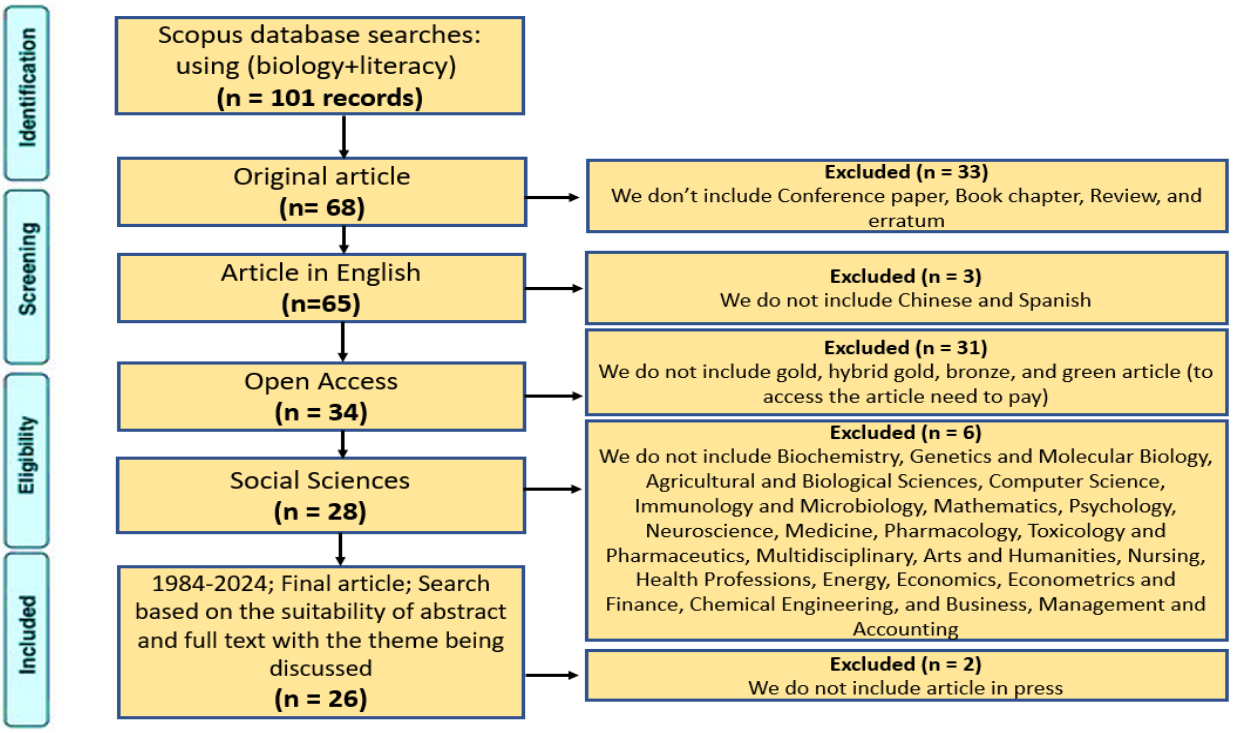

Figure 1. PRISMA flow diagram.

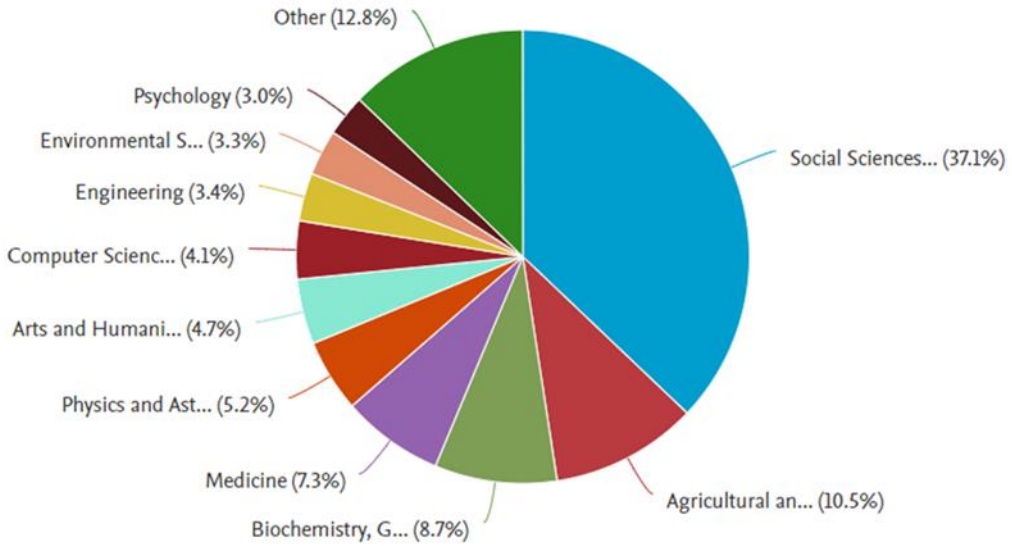

Figure 2. Document by subject area.

We focused the search with the phrase "biology+literacy" on a search within "article title", where the number of articles found was 101 (article status was 1987-2024). The search was carried out using the official subscription account owned by the Universitas Muhammadiyah Malang. Data simulation uses "Analyze search results" yang tersedia pada sistem Scopus. To enrich data and analysis, the data was exported to *CSV format (for visualize data process with VOSviewer) and *RIS (for synchronized with Mendeley). The search history in Scopus is as follows: TITLE (biology+literacy) AND (LIMIT-TO (DOCTYPE,

"ar")) AND (LIMIT TO (LANGUAGE, "English")) AND (LIMIT-TO (OA, "all")) AND (LIMIT-TO (SUBJAREA, "SOCI")) AND (LIMIT-TO (PUBSTAGE, "final")). The search yielded 101 articles, so they needed to be filtered (inclusion and exclusion) to focus the analysis. We use Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA), consists of four stages, namely identification, screening, eligibility, and inclusion (Selcuk, 2019). The sequence of inclusion and exclusion is shown in Figure 1. The articles analyzed focused on the subject area "social science" because biology education and learning are included in this subject area and considering that the dominant article (37.1%) is social sciences, as presented in Figure 2.

RESULTS AND DISCUSSION

Document by year

Figure 3 shows the number of articles in the Scopus database, annually from 2010 to 2023. Based on Figure 3, it can be seen that the trend of publications on biology and literacy in the Scopus database reached its peak in 2023. This data does not It can be fully used to conclude that in previous years the publication rate was low, because we only focused on original articles. It could be that other publications are in the form of books, conference papers, etc. This is also very likely to happen in 2024, which is still ongoing.

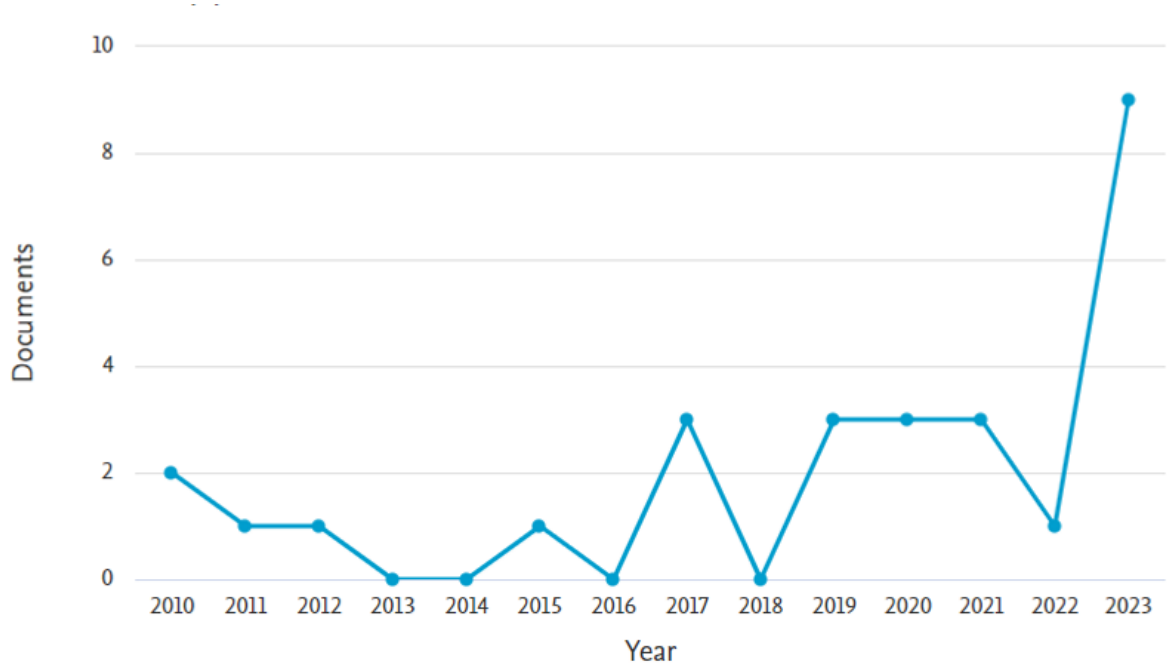

Figure 3. documents by year.

The high interest of scientists in studying biology and literacy in certain years, in this case for example 2023, could be influenced by technological developments, social needs and financial support. The pandemic increases the urgency of biological research for medical solutions (Kulkova et al., 2023; Lefrançois et al., 2023; Subbiah, 2023; Vonderschmitt et al., 2023), education and learning solutions (Nind et al., 2023; Shoaib et al., 2023; Z. Zhang & Gillespie, 2023), and public awareness (Jana et al., 2023; Maccaro et al., 2023; Perlman & Peiris, 2023), thereby opening up new opportunities in research. Financial support from government and the private sector also plays an important role, especially when there is a policy focus on health and environmental issues (Husamah et al., 2023; Jayaraman & Jambunathan, 2018; Lindsey et al., 2021; Mashfufah et al., 2018; Pham & Le, 2023). Additionally, new scientific

discoveries often trigger waves of additional research, and increased awareness and education about the importance of biology and scientific literacy encourage scientists to become involved in this field.

Author's country or territory

The trend of author's country or territory of research related to "biology and literacy" themes are presented in Figure 4.

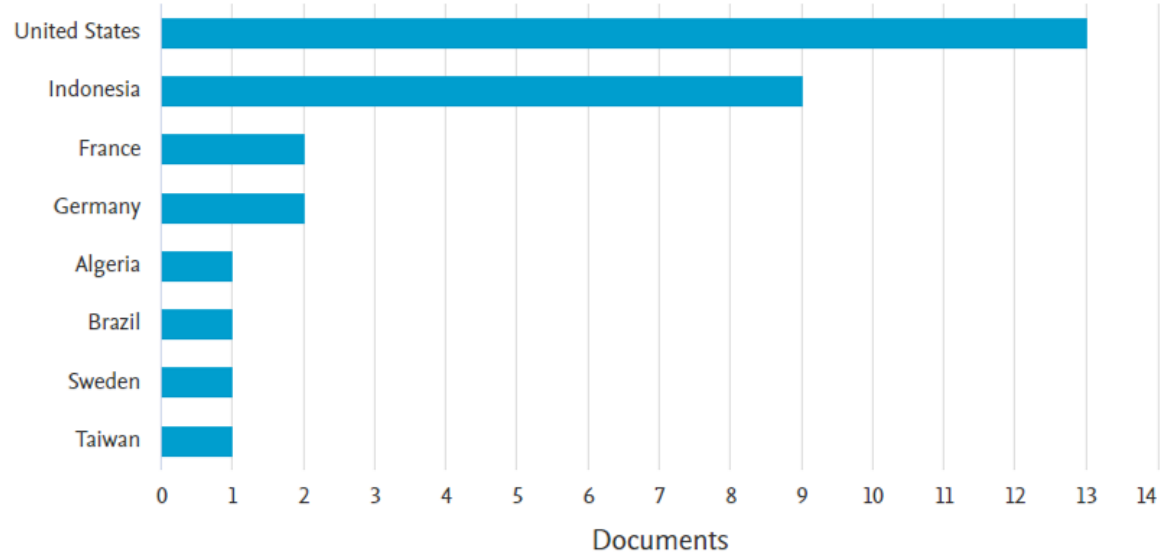

Figure 4. Author's country or territory.

Based on Figure 4, it can be seen that there are eight countries where the authors come from. The United States is the country of origin for scientists who have a high interest in biology and literacy themes. The interesting thing is that Indonesia is the second largest contributor. The themes of biology and literacy are developing in Indonesia in line with the response to education during the pandemic and the existence of an independent learning curriculum policy that emphasizes strengthening literacy.

Comparing the conditions of biology and literacy between one country, for example Indonesia, and other countries can provide significant benefits in the context of a more comprehensive study (Park & Kyei, 2011; Pfeffer, 2015; Zua, 2021). This comparative analysis can reveal patterns, trends, and factors that influence the connection between materials biology with reading-writing-communicating (literate) abilities in each country (Alneyadi et al., 2023; Cano, 2022). For example, differences in student literacy achievements can be explored. In addition, cross-country analysis can also identify best practices or innovations in other countries that can be adapted to improve literacy in Indonesia. By conducting a comprehensive comparative analysis, researchers and policy makers can gain a richer understanding of the dynamics of the interaction between biology and literacy, and formulate more effective interventions to encourage students' cognitive and academic development (Arce, 2018; Miller & McKenna, 2016; Rangkuti & Hidayat, 2022; Rodriguez-Segura, 2020; Shiel & Eivers, 2009; Silberstein, 2021).

The themes of biology and literacy have received a lot of attention from researchers in the United States because both are crucial fields for the development of science and technology (Howell & Brossard, 2021; Rudolph, 2024), as well as public health (Gormally & Heil, 2022; Tuttle. et al., 2023; Maria et al., 2023; Zamalloa et al., 2023). Biology as a basic science that studies life plays an important role in medical innovation, biotechnology and understanding the environment. On the other hand, literacy,

especially scientific/biological literacy, is essential to ensure that people can understand, evaluate and apply scientific information correctly in everyday life (Betz et al., 2023; Scheufele & Krause, 2019; Semilarski & Laius, 2021). Increasing focus on scientific literacy also contributes to empowering society in making decisions based on factual evidence, which ultimately encourages improvements in society's quality of life. This combination attracts the attention of researchers because of its broad and significant impact on social and technological progress.

The themes of biology and literacy have also received a lot of attention from researchers in Indonesia because of their relevance to the educational challenges faced by this country. Education policies in Indonesia, such as the 2013 Curriculum and the Merdeka Curriculum, emphasize the importance of science/biology literacy to improve students' HOTS and problem solving abilities (Betz et al., 2023; Scheufele & Krause, 2019). This is important to prepare the younger generation to face global challenges in the 21st century, including health, environmental, community/social and technological issues. Additionally, a strong understanding in biology helps in addressing public health issues, such as the COVID-19 pandemic (Hartono et al., 2023; Jimenez et al., 2022; Pedrosa et al., 2020; Suwono et al., 2017; Tulchinsky & Varavikova, 2014). Therefore, increasing scientific literacy and biology education is considered an important strategy to encourage educational progress and social welfare in Indonesia, which has subsequently sparked great attention from researchers from various universities in this field.

Literacy coverage and orientation

The scope of literacy related to biology which is the focus of researchers is presented in Table 1.

Table 1. Literacy coverage and orientation

No	Coverage of literacy	Reference	Number of references	Research orientation during Covid and before
1	Scientific/ science/ biological literacy	(Calado et al., 2015; Hartono et al., 2023; Kreher et al., 2021; Natale et al., 2021; Ridlo et al., 2022; Sarvary & Ruescha, 2023; Suwono et al., 2017; Washburn et al., 2023)	8	Scientific/science/biological literacy has also become the orientation of researchers, both during the COVID-19 period and before COVID-19
2	Information literacy	(Jankowski & Sawyer, 2019; Lantz & Dempsey, 2019; Weiner et al., 2011)	3	Not oriented to COVID-19
3	Quantitative Literacy	(Arsyad et al., 2023; Olimpo et al., 2018; Speth et al., 2010)	3	Quantitative literacy has also become the orientation of researchers, both during the COVID-19 period and before COVID-19
4	Visual literacy	(Newman. D. L, Spector, et al., 2023; Offerdahl et al., 2017)	2	Visual literacy has also become the orientation of researchers, both during the COVID-19 period and before COVID-19
5	Health literacy	(Fauzi et al., 2020; Suwono et al., 2023)	2	Health literacy has also become the orientation of researchers, during the COVID-19
6	Environmental literacy	(Rasis et al., 2023)	1	Environmental literacy has also become the orientation of researchers, during the COVID-19
7	Computer literacy	(Smolinski, 2010)	1	Not oriented to COVID-19

8	Three-dimensional literacy	(Kramer et al., 2012)	1	Not oriented to COVID-19
9	Reading literacy	(Ristanto & Darmawan, 2020)	1	Reading literacy has also become the orientation of researchers, during the COVID-19
10	Media literacy	(Proudfit, 2020)	1	Media literacy has also become the orientation of researchers, during the COVID-19
11	Assessment literacy	(Joachim et al., 2020)	1	Assessment literacy has also become the orientation of researchers, during the COVID-19
12	Epigenetic literacy	(Gericke & Mc Ewen, 2023)	1	Epigenetic literacy has also become the orientation of researchers, during the COVID-19
13	Digital literacy	(Arjaya et al., 2023)	1	Digital literacy has also become the orientation of researchers, during the COVID-19

Table 1 shows that scientific/ science literacy is identical to biology learning. Other types of literacy that are widely promoted by researchers are information literacy, quantitative literacy, health literacy, and visual literacy. There are eight other types of literacy that are also developed through biology learning, namely computer literacy, three-dimensional literacy, reading literacy, media literacy, assessment literacy, epigenetic literacy, digital literacy, and environmental literacy. If we look at the types of literacy that are very closely related to biology based on the vosviewer simulation (Figure 5), then the literacies that emerge are scientific/science literacy, information literacy, digital literacy, visual literacy, and environmental literacy.

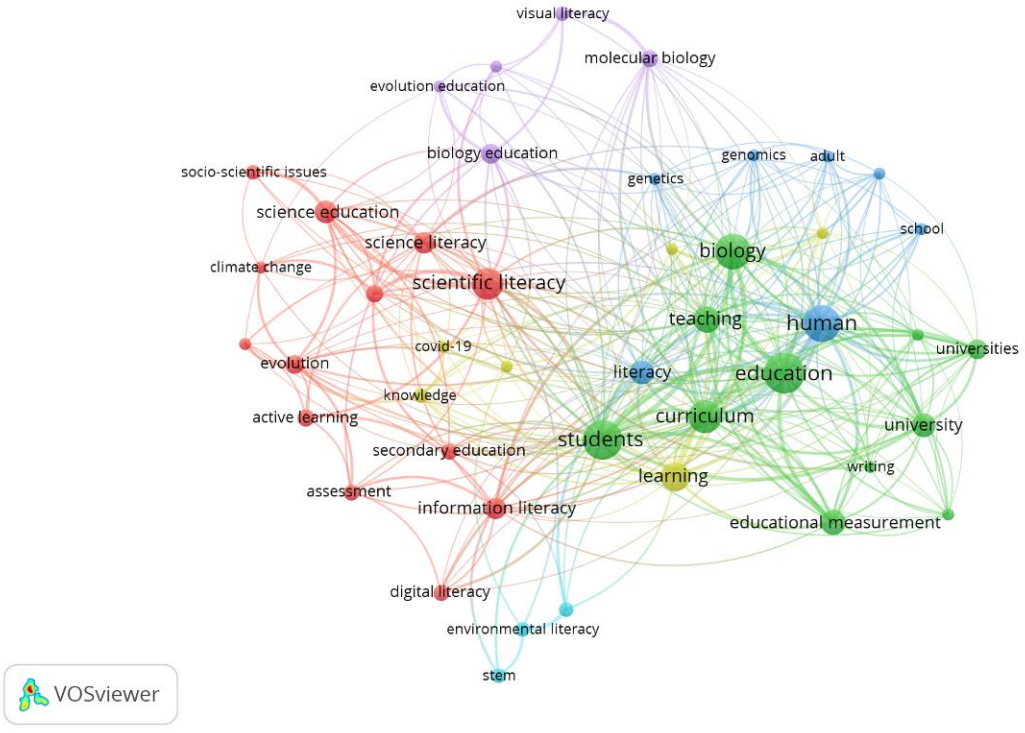

Figure 5. VOS-viewer display for type of analysis "Co-occurrence → keywords".

Biology learning has a crucial role in developing scientific/ science literacy because it gives students a deep understanding of the basic concepts of life and scientific processes. Through a learning approach based on experimentation, observation and data analysis, students are trained to think critically and solve problems scientifically. Scientific literacy formed from learning biology helps students understand complex environmental and health issues, as well as make decisions based on scientific evidence in everyday life (Nainggolan et al., 2021; Shaffer et al., 2019).

Thus, biology is also very relevant to health literacy and environmental literacy. These two aspects are closely related to the understanding of living organisms and their interactions with the environment. In the context of health literacy, learning biology provides basic knowledge that enables individuals to make better decisions regarding personal and societal health, such as nutrition, and healthy lifestyles (Kinoshita et al., 2024; Pradipta & Situmorang, 2024; Smith et al., 2021; Suwono et al., 2023). Meanwhile, in the context of environmental literacy, biology teaches about ecosystems, biodiversity and the impact of human activities on the environment. This knowledge is important for developing awareness and responsibility for nature conservation as well as actions that can reduce environmental damage (Ahirwar, 2024; Ardoin et al., 2020; Awaludin et al., 2024; Fang et al., 2023).

Biology is particularly relevant to information literacy and digital literacy because this discipline demands the ability to search, evaluate, and use information effectively using a variety of digital tools. In studying biology, students are often exposed to various sources of scientific information. They must be able to assess the credibility and accuracy of these sources, differentiate between fact and opinion, and organize relevant information to support their scientific understanding and arguments. Additionally, information literacy in biology involves using digital tools and scientific databases to find appropriate literature, as well as understanding and applying that information in the context of experiments and data analysis. These skills are critical not only in academic contexts, but also in everyday life, where individuals often have to make scientifically informed decisions, such as understanding health risks or complex environmental issues (Amin et al., 2023; Fitriani et al., 2023; Tauhidah & Wijayanti, 2023; Yusuf et al., 2022).

Biology is very relevant to quantitative literacy because many aspects of biology require understanding and application of mathematical and statistical concepts. This quantitative understanding allows one to analyze experimental data, make predictions, and construct mathematical models that describe biological phenomena. In addition, quantitative literacy in biology also involves skills in measuring, calculating, and visualizing data in the form of graphs and tables, which are important skills for effective scientific communication (Adler, 2018; Ardiansyah & Diella, 2017; Jamil et al., 2024; Nuraeni & Rahmat, 2019; Speth et al., 2010).

Biology is particularly relevant to visual literacy because this discipline often relies on visual representations to convey complex information. Many biological concepts, such as cell structure, the process of photosynthesis, the life cycle of organisms, and ecosystem networks, are easier to understand through diagrams, pictures, and visual models. Visual literacy in biology involves the ability to read, interpret, and create these visual representations. Biology also needs visualization, for example regarding experimental data in the form of graphs or diagrams to convey their findings clearly (Beckham et al., 2024; Brandstetter et al., 2017; Hilliker & Grayson, 2022; Menendez et al., 2024; Newman, D. L., Hannah, et al., 2023; Zhang, K. E. & Jenkinson, 2024).

In the future, as biology develops, it is predicted that related types of literacy will also increase. Media literacy is expected to have a vital role. Biology has a close relationship with media literacy because a lot of information related to biology is conveyed through various

media platforms, including news articles, documentaries, social media and popular scientific publications (Capati, 2020; Chen et al., 2023; Gardner et al., 2009; Proudfit, 2020; Risnani, 2021; Wu et al., 2019). Media literacy in a biological context means the ability to critically assess and analyze information presented by the media regarding biological issues such as climate change, pandemics, biotechnology, and public health (Hung et al., 2021; Nemati-Anaraki et al., 2021; West & Bergstrom, 2021). The general public needs to understand how to differentiate accurate, evidence-based information from fake news/infodemics or sensationalism.

Table 1 shows that most types of literacy covered in research are oriented to the COVID-19 issue, especially scientific or science/ biological literacy, quantitative literacy, visual literacy, health literacy, environmental literacy, reading literacy, media literacy, assessment literacy, epigenetic literacy, digital literacy. Even though the data shows that information literacy was not found to be related to Covid-19 (this could be due to publications not being recorded or articles not being published in journals), this is still important because it is still related to reading literacy, media literacy and digital literacy.

Various types of literacy, including those that can be developed through biology learning, need to be oriented to the problem of the COVID-19 pandemic because this has urgency and strategic benefits. The COVID-19 pandemic has had a significant impact on various aspects of life, requiring the strengthening of various literacy skills to be able to understand, analyze and respond effectively (Alizadeh et al., 2023; Irwin et al., 2022; Ludewig et al., 2022; Pokhrel & Chhetri, 2021). For example, health literacy is needed to understand information and steps to prevent COVID-19 (Moustafa & Kassem, 2023; Nakayama et al., 2022), digital literacy is needed to access information and services online (Beaunoyer et al., 2020; Campanozzi et al., 2023), and science/scientific literacy is needed to understand the process of spreading the virus, developing vaccines, and the policies taken (Qin et al., 2024; Reiss, 2020). By linking the development of various literacies in biology learning with actual issues such as the COVID-19 pandemic, students are expected to be able to gain knowledge and skills that are relevant and have a direct impact on their lives. This effort can certainly increase students' motivation and connection with learning, as well as strengthen the role of biology in solving the real and factual challenges they face.

CONCLUSION

This SLR obtained several interesting findings. It was found that the theme of biology and literacy reached its peak in 2023. This data does not It can be fully used to conclude that in previous years the publication rate was low, because this SLR focused on original articles. The United States is the country of origin for scientists who have a high interest in biology and literacy themes. The interesting thing is that Indonesia is the second largest contributor. This SLR also found that scientific/ science literacy is identical to biology learning. Other types of literacy that are widely promoted by researchers are information literacy, quantitative literacy, health literacy, and visual literacy and eight other types of literacy that are also developed through biology learning, namely computer literacy, three-dimensional literacy, reading literacy, media literacy, assessment literacy, epigenetic literacy, digital literacy, and environmental literacy. Most of this literacy is also oriented to the problems of the COVID-19 pandemic.

Based on the conclusions of this SLR, there are several important implications for future policy and research regarding the relationship between biology and literacy, namely (1) the trend of increasing publications on this theme indicates a high need and interest from the academic community, so that it can be a consideration for policy makers to encourage and facilitate collaborative research at both

national and international levels; (2) Indonesia's position as the second largest contributor to publications shows potential that can be developed, including expanding cross-country research to identify influencing factors and best practices; (3) the finding that scientific/ scientific literacy is identical to biology learning, as well as various other types of literacy that can be developed through biology learning, can be the basis for developing curriculum and innovative learning models that integrate the development of literacy skills comprehensively. Thus, these implications can encourage policies and research that will increasingly have an impact on improving the quality of biology learning and student literacy in the future.

We recommend for future, especially in the Indonesian context, that biology learning needs to be oriented towards strengthening students' literacy aspects. Various types of literacy, as has been promoted in various publications mentioned in this SLR and other potential literacies, need to be of concern to teachers/lecturers. Thus, biology learning in Indonesia will really have a significant impact and role in developing literacy.

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