Research Trends of SDGs Integrated Science Interactive Learning Media to Improve Students' Science Literacy: Bibliometric Analysis

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Abstract: This study examines the trend of interactive science learning media integrated with SDGs to improve students' science literacy. Improving science literacy is considered important considering the complexity of global challenges that require scientific understanding in sustainable decision-making. This study aims to provide a bibliometric review of publications related to interactive science learning media integrated with SDGs to improve students' science literacy during the period 2015-2024. Data were collected from Google Scholar using analysis tools such as Publish or Perish and Dimension.ai, resulting in 1,000 documents identified and selected using the PRISMA guidelines. The analysis was carried out using bibliometric and content analysis methods, supported by VOSviewer software to visualize keyword trends and emerging research patterns. The results show a significant increase in the trend of publications of interactive science media integrated with SDGs, with a peak in 2023. The dominance of keywords such as "citizen science," "sustainability," and "media literacy" indicates the important role of science literacy in preparing students to face global issues through critical thinking skills, collaboration, and digital literacy. The results of this study indicate that interactive learning media based on SDGs has become the main focus in the development of science education that is relevant and contextual to the needs of the 21st century. Although there are challenges in its implementation, the integration of SDGs in science education makes a significant contribution in creating a generation that is more aware of sustainability and is globally responsible.

Keywords: Interactive Science Media; SDGs; Science Literacy

Introduction

Science education plays a key role in shaping future generations capable of facing global challenges, including those listed in the Sustainable Development Goals (SDGs) (Garcia et al., 2017). The SDGs are designed to address 17 key issues. To achieve these goals, education needs to play a role in equipping students with knowledge and skills that are not only academic but also applicable in everyday life (UNESCO, 2017). One important aspect of this education is scientific literacy, which includes the ability to understand scientific concepts and use them in decision-making relevant to global issues (Almeida et al., 2023).

Improving scientific literacy is becoming increasingly important as the problems faced by the world today become increasingly complex. Scientific literacy includes not only an understanding of scientific facts and theories, but also the ability to apply that knowledge to solve real problems. Therefore, science education in schools needs to be designed to be relevant to today's needs, especially in the context of the SDGs.

With good scientific literacy, students can be more empowered to understand global issues and find sustainable solutions (OECD, 2019).

Interactive learning media has been proven effective in increasing student engagement in science learning (Astuti et al., 2020; Jacob & Centofanti, 2024). Interactive media is able to present more dynamic materials, thus helping students understand abstract concepts more easily (Aripin & Suryaningsih, 2019; Widodo et al., 2020). In addition, interactive media also provides opportunities for students to engage in virtual simulations and experiments, which in turn can improve their conceptual understanding (Elme et al., 2022; Tsivitanidou et al., 2021). By utilizing technology, interactive learning media is one solution to improve the quality of science education.

The integration of SDGs in interactive learning media is a strategic step to ensure that science education does not only focus on knowledge transfer, but also on instilling sustainability values. Through this integration, students not only learn about science, but also how science can play a role in solving global problems such as climate change, food security, and natural resource management (Hogan & O'Flaherty, 2022; Walid & Luetz, 2018). Thus, science education integrated with SDGs can help shape students into individuals who think critically and are globally responsible.

One of the main goals of integrating SDGs into science education is to raise students' awareness of the importance of sustainability in every aspect of life. Interactive learning media that carries the theme of SDGs can present real-world scenarios that allow students to understand how scientific decisions can affect human life and the environment in the future (Dukanwojo, 2023; Mahaisavariya & Charmondusit, 2023). This is expected to motivate students to be actively involved in finding innovative solutions to achieve sustainable development. In addition to improving scientific literacy, integrating SDGs into interactive learning media can also help students develop 21st-century skills such as critical thinking, collaboration, communication, and creativity. These skills are essential to face an increasingly complex and challenging world. By using interactive learning media, students are invited to be more active in the learning process, which in turn can improve their higher-order thinking skills (Salame & Nazir, 2019; Silva et al., 2022).

However, although the potential of SDGs-integrated interactive learning media is quite large, there are still challenges in its implementation. One of the main challenges is the readiness of schools and teachers to adopt this technology effectively. Some schools may still have limited access to adequate technological devices, while teachers may need additional training to master the use of interactive media in learning (Trechsel et al., 2022; Wals, 2019). Therefore, support is needed from various parties, including the government and educational institutions, to facilitate the adoption of this media in the school environment.

Several studies have shown that the use of interactive learning media can improve students' understanding of science concepts, especially when integrated with real-world contexts such as the SDGs. However, there are still few systematic studies exploring the impact of this integration on improving students' scientific literacy. Therefore, it is important to conduct a comprehensive literature review to understand the extent to which interactive learning media integrated with the SDGs can contribute to improving students' scientific literacy and skills in facing global challenges.

Given the importance of interactive science learning media integrated with SDGs, this study aims to review research trends related to interactive science learning media integrated with SDGs during the period 2015-2024. Thus, the results of this review are expected to be a reference for the development of more innovative and effective educational practices in order to support the achievement of SDGs and to improve students' science literacy in Indonesia, as well as provide significant contributions to future education policies.

Method

This research method is descriptive and analytical, which aims to understand and describe research trends related to interactive science learning media integrated with SDGs to improve students' science literacy. The data used in this study were obtained from information sources indexed by Google Scholar using analysis tools such as Publish or Perish and Dimension.ai. To conduct a search on Google Scholar, keywords related to research trends in interactive science media integrated with SDGs to improve students' science literacy were used.

In this study, the analysis was conducted on 1,000 documents that have been indexed by Google Scholar between 2015 and 2024. The Google Scholar database was chosen as a source for document search because Google Scholar applies consistent standards in selecting documents included in its index, and displays more documents compared to other databases, especially in the field of educational research (Hallinger & Chatpinyakoop, 2019; Hallinger & Nguyen, 2020).

The use of Google Scholar also allows researchers to get a broader picture of scientific publications, conference articles, and other reference materials related to interactive science learning media integrated with SDGs in improving students' science literacy. To filter the data that has been collected through Publish or Perish, researchers use the Preferred Reporting Items for

Systematic Reviews and Meta-Analyses (PRISMA) guidelines. This process includes the stages of identification, selection, and evaluation of document quality, which are carried out to ensure that only documents that are relevant and in accordance with the research topic are included in the analysis. The selection stage includes the removal of irrelevant documents, as well as the evaluation of document quality based on the number of citations and content relevance.

After the screening stage, the data were analyzed using bibliometric analysis and content analysis methods to identify research trends, key themes, and emerging patterns in the application of SDGs-integrated interactive science media to improve students' scientific literacy. Bibliometric analysis was conducted with the help of software such as VOSviewer to visualize the relationship between keywords frequently used in research, so that it can show emerging trends and areas that need further exploration. The results of this analysis are expected to provide a comprehensive picture of the effectiveness of SDGs-integrated interactive science media, innovations that have been implemented, and challenges and opportunities in developing students' scientific literacy through this approach.

Results and Discussion

This study aims to describe research trends related to interactive science media integrated with SDGs to improve science literacy conducted from 2015 to 2024. Research documents on the trend are taken from scientific publications indexed by Dimensions.ai. Figure 1 below shows the publication trend on interactive science media integrated with SDGs to improve science literacy from 2015 to 2024.
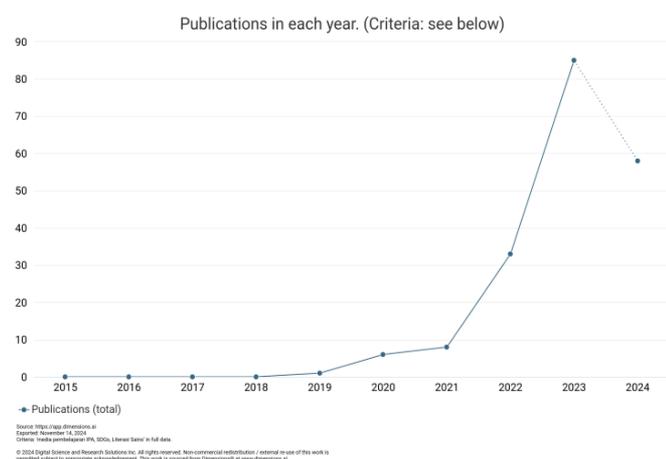

Figure 1. Research trends on interactive science media integrated with SDGs to improve science literacy.

Figure 1 shows that the research trend on interactive science media integrated with SDGs to improve students' science literacy from 2015 to 2023 has increased significantly every year. In 2023, the number of publications peaked with around 80 publications. However, in 2024, this trend showed a slight decline with the number of publications below 60.

The steady increase from 2015 to 2023 reflects the growing interest among academics and educational practitioners in interactive media integrated with SDGs goals as a means to improve students' scientific literacy. In 2015, there were relatively few publications related to interactive media in science learning connected to SDGs and scientific literacy, and the number continues to increase along with the increasing awareness of the importance of scientific literacy in equipping students with 21st century skills, such as critical thinking, analytical skills, and problem solving.

This increasing research trend indicates a consistent effort to understand the best ways to develop interactive media that can integrate SDGs and improve students' scientific literacy. It also reflects innovation in science learning approaches that are more contextual and relevant to global issues. The decreasing trend in 2024 may be due to various factors, such as a shift in research focus to newer areas, changes in education policies, or challenges in implementing SDG-based interactive media at various levels of education. However, the overall trend shows a significant increase, providing evidence that integrating SDGs into science learning for scientific literacy remains a relevant and important topic in science education. Table 1 is also presented below, which displays research on SDG-integrated interactive science media to improve scientific literacy by publication type.

Table 1. Research trends on SDGs-integrated interactive science media to improve science literacy based on publication type.

Publication Type	Publications
Article	121
Edited Book	68
Chapter	2
Monograph	1

Based on Table 1, it is known that research on interactive science media integrated with SDGs to improve students' science literacy is found in several types of publications. The form of articles is the most numerous type of publication, with 121 documents, followed by edited books with 68 documents, chapters with 2 documents, and monographs with 1 document.

The research trend of interactive media for integrated science SDGs in the form of articles shows that scientific articles are the dominant media in disseminating research results related to this topic. Articles are chosen because they allow researchers to

present their findings comprehensively and can reach a wider audience through scientific journals published in print and online. This reflects the importance of articles as the main means of disseminating research results in a formal and structured manner.

Meanwhile, the least publication type is monograph, which only records 1 document. Although the number of monographs is low, this type of publication usually provides a more in-depth and comprehensive analysis of a particular topic. Edited books also play an important role in supporting the dissemination of research results by collecting various studies in one volume, which provides a broader perspective on the topic of interactive science media and science literacy integrated with the SDGs.

Overall, these data indicate that SDGs-integrated interactive science media for science literacy has received significant attention in the academic community, with a major focus on article publications. The dominance of articles as a form of publication indicates the need to convey scientific information on this topic in a formal and structured manner, as well as the importance of science literacy as a core competency in the 21st century. This trend also reflects a growing understanding of the importance of contextual and relevant interactive media to global issues in improving students' science literacy. Table 2 is also presented below, which displays the top ten (10) main sources of research trends on SDGs-integrated interactive science media for improving science literacy that are frequently cited by other researchers on this topic.

Table 2. Top 10 main sources of SDGs-integrated interactive science media trends to improve science literacy (2015-2024)

Name	Publications	Citations	Citations Mean
Advances in Social Science, Education and Humanities Research	42	53	1.26
Jurnal Penelitian Pendidikan IPA	15	8	0.53
Advances in Economics, Business and Management Research	7	0	-
JPBI (Jurnal Pendidikan Biologi Indonesia)	5	14	2.80
Jurnal Pengabdian dan Pemberdayaan Masyarakat	5	4	0.80
Jurnal Pendidikan MIPA	4	2	0.50
Jurnal Pendidikan Ilmu Pendidikan	3	1	0.33
Jurnal Pendidikan IPA Indonesia	2	20	10.00
JTK (Jurnal Tadris Kimia)	2	3	1.50
Jurnal Obsesi Jurnal Pendidikan Anak Usia Dini	2	13	6.50

Table 2 shows that research related to interactive science media integrated with SDGs to improve students' science literacy has developed in various publication sources. Advances in Social Science, Education and Humanities Research is the main source with the largest number of publications (42) and a total of 53 citations, indicating that this journal is the main platform for disseminating research in this field.

Despite its fewer publications, Jurnal Pendidikan IPA Indonesia has the highest average citation (10.00), indicating that the articles published here have significant quality and impact in SDGs integrated science literacy research. The same thing is also shown by Jurnal Obsesi Jurnal Pendidikan Anak Usia Dini which has a high average citation (6.50) even though the number of publications is only two, indicating that research related to this topic published in the journal is quite influential.

JPBI (Jurnal Pendidikan Biologi Indonesia) also stands out with an average citation of 2.80 from five publications, indicating that the research in this journal has a quality that is recognized in the academic community, especially in the context of biology education and SDGs integration.

Overall, these data reflect that interactive science media integrated with SDGs to improve students' science literacy has become a relevant and growing topic in the academic realm. The dominance of Advances in Social Science, Education and Humanities Research in the number of publications indicates that this journal is the main choice for researchers to disseminate their findings. Meanwhile, journals with high average citations indicate that there are publications that have a significant impact even though they are not in large numbers. This trend indicates a continued interest in the development of interactive media in science learning, with the aim of strengthening students' science literacy through an approach that is integrated with the SDGs goals. Table 3 is also presented below, which displays the ten (10) most frequently cited article titles in research on interactive science media integrated with SDGs to improve science literacy.

Table 3. Top 10 key citations of SDGs-integrated science interactive media trends to improve science literacy (2015-2024)

Cites/year	Year	Author	Title
32.75	2020	Queiruga-Dios, M. Á., López-Iñesta, E., Diez-Ojeda, M., Sáiz-Manzanares, M. C., & Vázquez Dorrío, J. B.	Citizen Science for Scientific Literacy and the Attainment of Sustainable Development Goals in Formal Education
57.00	2023	Kumar, P., Sahani, J., Rawat, N., Debele, S., Tiwari, A., Emygdio, A. P. M., ... & Pfautsch, S.	Using empirical science education in schools to improve climate change literacy
16.00	2022	Sanabria-Z, J., Alfaro-Ponce, B., González Peña, O. I., Terashima-Marín, H., & Ortiz-Bayliss, J. C.	Engagement and social impact in tech-based citizen science initiatives for achieving the SDGs: a systematic literature review with a perspective on complex thinking
9.00	2020	Veronica, R., & Calvano, G.	Promoting sustainable behavior using serious games: Seadventure for ocean literacy
9.80	2019	Amos, R., & Levinson, R.	Socio-scientific inquiry-based learning: An approach for engaging with the 2030 Sustainable Development Goals through school science
43.00	2022	Maryanti, R. I. N. A., Rahayu, N. I., Muktiarni, M., Al Husaeni, D. F., Hufad, A. C. H. M. A. D., Sunardi, S., & Nandiyanto, A. B. D.	Sustainable development goals (SDGs) in science education: Definition, literature review, and bibliometric analysis
6.25	2020	Buslón, N., Gairal, R., León, S., Padrós, M., & Reale, E.	The scientific self-literacy of ordinary people: Scientific dialogic gatherings
38.25	2020	Radovanović, D., Holst, C., Belur, S. B., Srivastava, R., Houngbonon, G. V., Le Quentrec, E., ... & Noll, J.	Digital literacy key performance indicators for sustainable development
24.00	2020	Shulla, K., Leal Filho, W., Sommer, J. H., Salvia, A. L., & Borgemeister, C.	Channels of collaboration for citizen science and the sustainable development goals
16.33	2021	Jeong, S., Sherman, B., & Tippins, D. J.	The Anthropocene as we know it: Posthumanism, science education and scientific literacy as a path to sustainability

The research data shows that the integration of interactive media in science education integrated with SDGs has become a major focus in efforts to improve science literacy. The article by Kumar et al. in 2023 was the most cited, with 57 citations per year, which emphasized the importance of empirical evidence-based science education to improve climate change literacy among students. This shows great attention to the impact of science education in building students' awareness and understanding of global issues.

The study by Radovanović et al. in 2020, which received 38.25 citations per year, also stands out with its focus on key performance indicators in digital literacy to support sustainable development. This high citation rate indicates that digital literacy is considered an important competency in supporting the achievement of the SDGs, which is relevant to the needs of interactive and technology-based science learning.

In addition, research by Maryanti et al. in 2022 which reviewed and analyzed bibliometrics on SDGs in science education had an average citation of 43 per year. This study shows that a literature-based approach is very important to provide a strong conceptual basis in the implementation of SDGs in education, including in science literacy.

Overall, this trend illustrates that research on interactive science media integrated with SDGs continues to grow with innovative approaches aimed at improving science literacy. This phenomenon shows the importance of research continuity in developing learning models that are responsive to 21st century challenges, such as climate change and digital literacy, as well as commitment to SDGs. Table 4 below displays the ten (10) most frequently used keywords in research on interactive science media integrated with SDGs to improve science literacy. These keywords reflect important elements related to the implementation and success of interactive science media in science education.

Table 4. Ten keywords in the trend of SDGs-integrated interactive science media to improve science literacy (2015-2024)

Terms	Occurrences	Relevance
SDGs target	3	2.58
Media literacy	4	2.03
Information literacy	3	1.94
Numeracy	3	1.61
PISA	3	1.19
Digital skill	3	1.13
Un sustainable development goal	3	1.10
Sustainability	6	0.97
Implementation	5	0.96
Citizen science	13	0.80

From the table above, it can be seen that the term "Citizen science" has the highest frequency of occurrence with 13 times, indicating the high relevance of this concept in the context of interactive science media integrated with SDGs to improve science literacy. Citizen science reflects community involvement in the scientific process, which can support the achievement of SDGs and strengthen science literacy among students by providing them with direct experience in scientific research.

The terms "Sustainability" and "Implementation" also appeared frequently, with 6 and 5 occurrences respectively, indicating the importance of sustainability and strategy implementation in supporting SDG-based science literacy. This reflects the need to integrate sustainability principles into science education and encourage effective implementation of learning models that incorporate SDGs.

In addition, "Media literacy" and "Information literacy" also have quite high relevance. This shows that in the context of science literacy, media and information literacy skills are considered important to help students understand and analyze scientific information critically. Both reflect the need for critical thinking skills and the ability to understand various sources of information related to science and the SDGs.

The emergence of the terms "PISA" (Programme for International Student Assessment) and "Digital skills" is also important. PISA is often used as a reference in measuring science literacy globally, thus showing that the development of interactive science media integrated with the SDGs is not only locally relevant but also has international competitiveness. Meanwhile, digital skills are needed in increasingly developing technology-based learning, which supports digital literacy skills in the context of the SDGs.

Overall, these data show that the integration of interactive science media to support science literacy focused on SDGs covers important aspects such as citizen science, sustainability, information literacy, digital skills, and global standards such as PISA. This trend shows a commitment in science education to prepare students with relevant skills for global challenges in the 21st century.

The results of bibliometric mapping for the shared keyword network in articles related to the topic of SDGs-integrated interactive science media to improve science literacy are shown in Figure 2.

Figure 2 shows the results of bibliometric keyword mapping on research trends on interactive science media integrated with SDGs to improve science literacy. This visualization illustrates the network of keywords frequently used in research related to science literacy, showing the relationship between key concepts such as "sustainable development goal," "citizen science," "education," "technology," and "literacy."
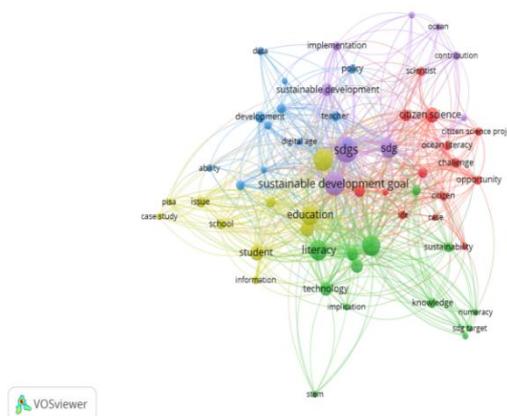

Figure 2. Network visualization of research trends on interactive science media integrated with SDGs to improve science literacy.

This network map consists of several clusters marked with different colors, indicating the relationship between keywords in the context of SDGs-integrated science literacy research: (1) Red Cluster; Includes terms such as "citizen science," "science literacy," and "opportunity." This cluster shows a focus on the role of citizen science in supporting SDGs and improving science literacy through community involvement in the scientific process. (2) Green Cluster; Contains keywords such as "education," "technology," and "student." This cluster emphasizes the importance of education and technology in supporting science literacy based on SDGs, as well as the role of technology in improving students' learning experiences. (3) Blue Cluster; Featuring terms such as "sustainable development," "policy," and "development." This cluster focuses on sustainability policies and efforts relevant to the SDGs, indicating the importance of policy support in implementing sustainable science education. (4) Purple Cluster; Includes terms such as "implementation" and "contribution," indicating a focus on the tangible contributions of science literacy research to achieving the SDGs as well as the implementation of these concepts in science learning. (5) Yellow Cluster; Contains keywords such as "PISA," "school," and "case study." This cluster demonstrates case study-based approaches and international standards such as PISA to measure students' science literacy at the global level, relevant to efforts to ensure educational outcomes are aligned with international standards.

This keyword network provides insight into the latest research trends in the application of interactive science media integrated with SDGs to improve science literacy, by showing how concepts such as technology,

citizen science, and sustainability policies are used to develop various scientific competencies. This visualization indicates the direction of future research, namely improving science literacy that supports global sustainability goals. Furthermore, the results of the overlay visualization on the research trends of interactive science media integrated with SDGs to improve students' science literacy are presented in Figure 3.
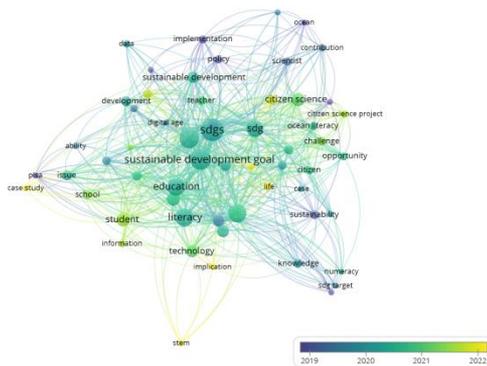

Figure 3. Overlay visualization of research trends on SDGs-integrated interactive science media to improve students' science literacy.

The figure above shows an overlay visualization of research trends on interactive science media integrated with SDGs to improve students' science literacy. This visualization uses a color scale to indicate the year in which a particular keyword appeared in the research, with dark blue indicating older research (2019) and yellow indicating newer research (2022).

In Figure 3, several key keywords stand out and appear frequently in the research trends, such as "sustainable development goal," "SDGs," "education," and "literacy." These keywords are located at the center of the network, indicating that this topic has a strong relationship with the concept of science literacy and interactive media used to connect science learning with SDGs goals.

Keywords such as "technology," "student," and "STEM" also appear in this visualization, in lighter shades, indicating that they are frequently used in recent research. This reflects the current trend in science education to integrate technology and STEM approaches to improve science literacy and relevance to the SDGs. Other keywords, such as "citizen science," "sustainability," and "numeracy," are also seen in lighter areas, indicating recent interest in linking science to civic engagement and sustainability. The presence of the terms "PISA" and "case study" indicates that many studies utilize case studies and international standards such as PISA to measure students' science literacy.

Overall, this visualization provides an overview of how interactive media research in science education

related to the SDGs continues to evolve. Key research focuses include technology integration, STEM approaches, science literacy skills, and sustainability, all of which are relevant to the global goals of sustainable education.

In addition, keywords are also presented for research on interactive science media integrated with SDGs to improve students' science literacy based on density visualization. Figure 4 below shows the density visualization. The density of the research theme is displayed in bright yellow, indicating the frequency of use of certain keywords in the literature. The brighter the color of a theme, the more research has been done on that theme, and conversely, the dimmer the color, meaning that the theme is rarely studied (Hudha et al., 2020; Kholik et al., 2023).
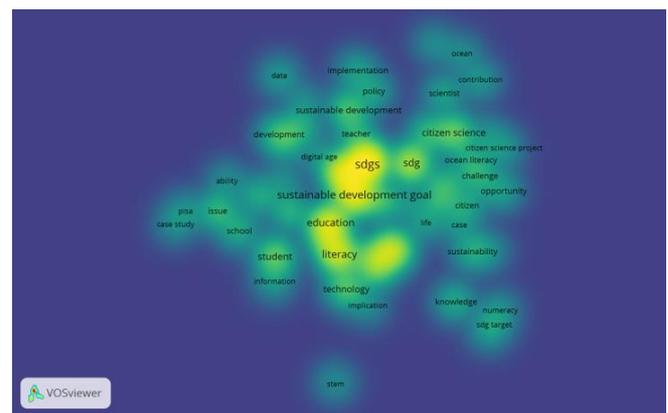

Figure 4. Density visualization of research trends on interactive science media integrated with SDGs to improve students' science literacy.

Some keywords with dim colors such as "STEM", "numeracy", and "PISA" indicate that these themes have not been widely discussed in research related to the integration of SDGs in interactive science media. Therefore, these keywords can be an opportunity for further research in the context of science literacy with an arrival-based educational approach. In contrast, keywords marked with bright yellow such as "SDGs," "sustainable development goals," and "literacy" are the most frequently appearing in related studies, reflecting the main focus of research on improving science literacy through an educational approach that focuses on SDGs.

Overall, research on the application of SDGs in science literacy is highly relevant to the needs of 21st-century education. This integration helps students understand science concepts in a way that is directly related to global goals, while developing critical thinking, collaboration, and environmental literacy skills (Ferreira et al., 2021; Queiruga-Dios et al., 2020; Radovanović et al., 2020). Through an SDG-relevant approach, students can see the relevance between science and everyday life, thereby strengthening their

motivation to learn and their concern for environmental and social issues (Astuti et al., 2020; Primasti, 2021).

In the next few years, research on integrated science literacy SDGs is expected to continue to grow. One promising direction of development is the use of interactive technology to connect SDG concepts with local contexts, such as cultural or environmental preservation (Zinchenko et al., 2021). For example, using projects that focus on marine conservation or environmentally friendly farming practices in rural areas will improve students' understanding of scientific concepts with real applications (Ardoin et al., 2020; Cardoso-Andrade et al., 2022).

This contextual approach not only enriches students' learning experience but also fosters critical and creative thinking skills as they seek innovative solutions to real-world problems in their projects. In addition, by studying learning with SDGs issues, students will better understand the importance of the role of science in achieving sustainable development. Thus, research trends in this area not only strengthen scientific literacy but also other crucial 21st-century skills such as communication, collaboration, and problem-solving.

Conflicts of Interest
We have no conflict of interest.

Conclusion

Based on the analysis of research trends on interactive science media integrated with SDGs to improve science literacy from 2015 to 2024, it can be seen that this topic is increasingly attracting researchers' interest. The number of publications continues to increase each year until it peaks in 2023, although it experiences a slight decline in 2024. This trend reflects the increasing awareness of the importance of integrating SDGs in science learning to develop science literacy that is relevant to the challenges of the 21st century.

In terms of publication types, scientific articles are the dominant form, indicating that researchers choose this medium to disseminate their research results widely. In addition, several frequently cited journals, such as Advances in Social Science, Education and Humanities Research and Jurnal Pendidikan IPA Indonesia, show their important role in supporting the development of science literacy integrated with the SDGs.

This study also shows that keywords such as "citizen science," "sustainability," and "media literacy" are frequently used, indicating that global issues, community involvement in the scientific process, and media literacy play an important role in achieving the SDGs. The keyword network visualization displays several key concept clusters, such as technology, education, sustainability policies, and international standards, which are relevant to developing contextual and measurable science literacy.

This research trend shows the current commitment of education to support the achievement of SDGs through interactive media innovation in science education, which aims to equip students with the scientific competencies needed to face global challenges.

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