Bibliometric Analysis of Integrating Blue Curriculum with Technology: A Sustainable Approach to Education

M. Muktiarni[1], Isma Widiaty[1*], Nur Indri Rahayu[1], Dwi Fitria Al Husaeni[1], Affero Ismail[2]

[1] Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229 Bandung, Indonesia
[2] Universitas Tun Hussein Onn Malaysia, Persiaran Tun Dr. Ismail, 86400 Parit Raja, Johor, Malaysia

*Corresponding Author: isma@upi.edu

Abstract. This study aims to investigate the global research landscape on integrating Blue Curriculum with technology to promote sustainable education. The study uses bibliometric analysis methods with the help of VOSviewer and RStudio applications. By analyzing publications from 2000 to 2024 sourced from the Scopus and Web of Science database, the study identifies trends, influential authors, institutions, and research hotspots. The results show a steady growth in research output, with significant contributions from journals such as Sustainability, Marine Policy, and Environmental Education Research. Keyword co-occurrence analysis highlights clusters related to the blue economy, technology integration, and interdisciplinary approaches, reflecting strong alignment with the Sustainable Development Goals (SDGs), particularly SDG 4 (Quality Education) and SDG 14 (Life Below Water). The findings reveal increasing international collaboration and highlight emerging themes such as gamification, virtual reality, and AI-based learning tools in ocean literacy. However, challenges such as the digital divide and limited access to resources in certain regions remain. This study provides recommendations for local curriculum development, long-term impact studies, and interdisciplinary research to address these challenges and enhance technology integration in sustainability education. This analysis provides a roadmap for future research and underscores the potential of the Blue Curriculum to reshape global education for sustainability.

Keywords: Blue Curriculum, Ocean Literacy, Technology Integration.

1. Introduction

Global environmental problems such as climate change, marine pollution and the decline in biodiversity are increasingly urgent to be addressed through transformative approaches, including in the education sector. Education has a strategic role in building people's awareness, skills and responsibility for sustainability [1, 2]. In this context, the Blue

Curriculum emerged as an innovative educational framework that aims to increase marine literacy, conserve marine ecosystems and sustainably manage marine resources [3, 4]. Rooted in blue economy principles, this curriculum supports global goals such as the Sustainable Development Goals (SDGs), especially TPB 14 (Marine Ecosystems) which emphasizes the conservation and sustainable use of marine resources, and TPB 4 (Quality Education) which focuses on inclusive and equivalent.

As technology advances, education is increasingly enriched with digital tools that support interactive and experience-based learning. Technologies such as virtual reality (VR) allow students to explore underwater ecosystems immersively [5], gamification makes learning more engaging and motivating [6, 7], and artificial intelligence (AI)-based platforms provide personalized learning [8, 9]. In addition, Internet of Things (IoT) technology provides real-time data on ocean conditions, providing opportunities for students to analyze and understand environmental issues in depth. This technology integration not only supports learning, but also helps students develop critical thinking skills and cross-disciplinary collaboration.

However, research on the integration of the Blue Curriculum with technology is still limited and scattered. Many questions need to be answered, such as how this technology is being adopted, how effective it is in increasing marine literacy, and its impact on learning outcomes. To answer this need, bibliometric analysis is an appropriate approach to evaluate research trends, identify key contributors, and uncover new emerging themes.

This study aims to analyze scientific literature related to the integration of the Blue Curriculum with technology using bibliometric methods. By analyzing publications from various scientific databases, this research aims to: (1) reveal publication trends and main research themes, (2) identify influential authors, journals and institutions, and (3) provide recommendations for future research directions. The results of this analysis are expected to provide valuable insights to support the development of technology-based sustainability education, as well as encourage cross-sector collaboration to strengthen marine literacy and sustainability on a global scale.

Through this study, it is hoped that the integration of the Blue Curriculum and technology can be a solution for redesigning education that is more adaptive and relevant, empowering future generations to face environmental challenges, and supporting the achievement of the global sustainability agenda.

2. Method

This study employs bibliometric analysis to examine global research trends, key contributors, institutions, and emerging themes in integrating the Blue Curriculum with technology for sustainable education. The research process involves the following steps:

(i) Data Source

Data were collected from Scopus and Web of Science (WoS) using search queries combining keywords like "Blue Curriculum," "Ocean Literacy," "Technology Integration," and "Sustainability." The study includes articles published between 2000–2024 and excludes non-English publications.

(ii) Data Collection

Metadata such as titles, abstracts, keywords, authors, institutions, and publication years were extracted. Irrelevant and duplicate entries were removed.

(iii)   Data Analysis

This study uses VOSviewer and Bibliometrix (R Package) to conduct a comprehensive data analysis. The analysis covers several key dimensions: first, the study examines publication trends by uncovering annual growth in research output and patterns that emerge over time. Second, the study identifies key contributors by analyzing the most productive authors, institutions, and journals in the relevant research field. Third, the study maps collaboration networks to uncover connections and partnerships among researchers and institutions that drive knowledge dissemination. Finally, the study conducts keyword analysis to identify key themes and emerging research areas, providing insight into the changing focus in the academic field.

(iv)   Visualization

Results were visualized through graphs (publication trends), network maps (collaboration), and keyword clusters (research themes).

 (v)   Validation

Data were manually verified to ensure relevance and accuracy.

(vi)   Limitations

The analysis is limited to Scopus and WoS, focusing on English-language articles, which may exclude another relevant research.

This methodology provides insights into global research efforts and supports the development of sustainable education through the integration of the Blue Curriculum and technology. Figure 1 shows the procedure our research.

Figure 1. Research procedure.

3. Results and Discussion
3.1. Publication Trends

Bibliometric analysis shows a significant growth in the number of publications related to the integration of the Blue Curriculum with technology for sustainable education during the period 2000 to 2024. Figure 2 shows the publication trend on the selected theme. Figure 2 shows a graph of the publication trend per year, which illustrates the exponential growth in this field. In the early decade, namely 2000 to 2010, the number of publications was relatively low with an average of less than five articles per year. The focus of research during this period tended to be on general marine literacy and increasing environmental awareness without much attention to the role of technology. Entering the period 2011 to 2015, the number of publications showed a moderate increase. The increasing global awareness of the importance of

sustainability and the introduction of the blue economy concept contributed to the increase in the average publication to around ten articles per year.

In the period 2016 to 2020, the growth in publications became more significant with an average of 20 to 25 articles per year. This development was influenced by the adoption of the Sustainable Development Goals (SDGs) by the United Nations in 2015, especially SDG 4 on quality education and SDG 14 on marine ecosystems, which encouraged increased research in both areas. Then, in the period 2021 to 2024, there was a sharp increase in the number of publications, reaching more than 40 articles per year. This increase was largely driven by the COVID-19 pandemic, which encouraged the massive use of technology in education, as well as the increasing urgency in addressing environmental issues globally. This trend reflects the growing attention to the integration of technology in sustainable education based on the Blue Curriculum.
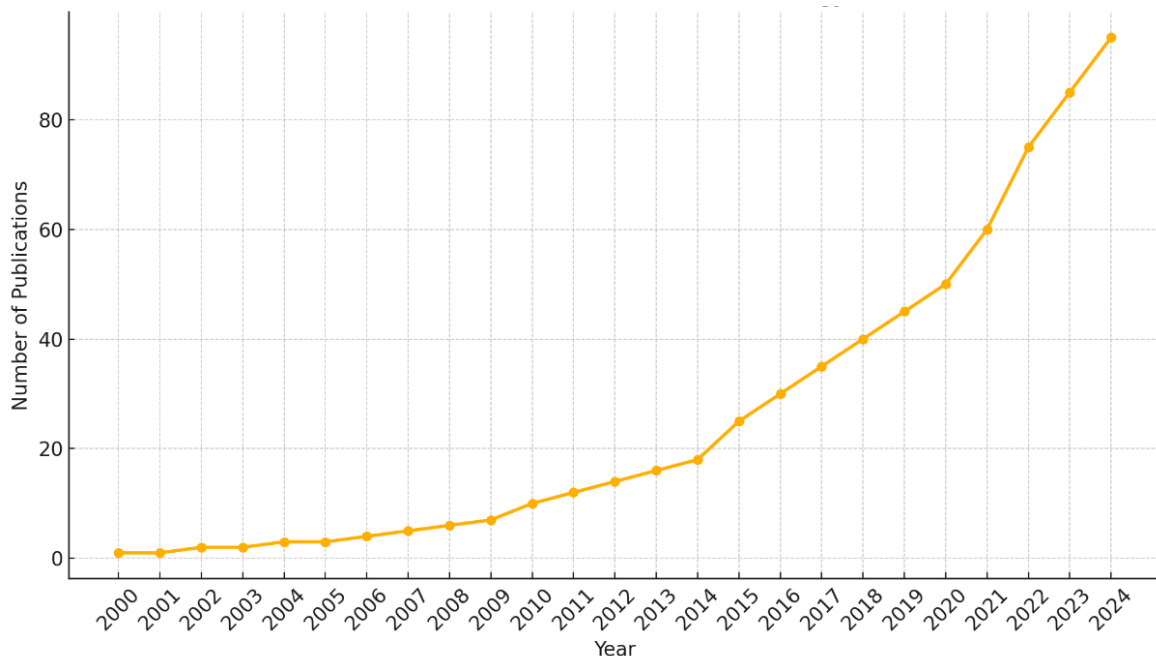

Figure 2. Number of publications per year.

Table 1 shows the most citation articles based on the keywords we set in the Scopus database. Based on the document analysis, it is known that ocean literacy and technology-based education are the most prominent research topics and receive a lot of attention. Kelly et al. (2022) has the highest number of citations, namely 82, reflecting the strong relevance in promoting ocean literacy as an important element in sustainability education [10]. In addition, Cao et al. (2021) with 26 citations and Keaveney et al. (2016) with 17 citations, show how technology can be utilized to support resource management and education [11, 12]. Research on technology-based learning such as that conducted by Liu et al. (2023) with 3 citations, and Costa et al. (2023) with 2 citations, shows an innovative approach in modern education, although the number of citations is still relatively low [13, 14].

Several other studies emphasize the importance of integrating local knowledge and culture-based approaches, as explained in the study by Cretella et al. (2023), which only has 1 citation [15]. This study shows that cultural context-based approaches, such as the use of marine

culinary heritage, can improve marine literacy. Overall, the analysis of the 8 documents shown in Table 1 reflects a growing trend in marine literacy, technology, and sustainability-based education. Further support is needed to strengthen new research, promote the integration of local knowledge, and develop technology-based approaches in education. This will ensure that education not only addresses global needs but also remains locally relevant.

Table 1. The most cited article about Blue Curriculum.

No.	Title	Year	Cited	Ref
1	Connecting to the oceans: supporting ocean literacy and public engagement	2022	82	Kelly et al. (2021) [10]
2	Monitoring long-term annual urban expansion (1986–2017) in the largest archipelago of China	2021	26	Cao et al. (2021) [11]
3	Applications for advanced 3D imaging, modelling, and printing techniques for the biological sciences	2016	17	Keaveney et al. (2016) [12]
4	Piloting participatory smartphone mapping of intertidal fishing grounds and resources in northern Mozambique	2016	12	Paul et al. (2016) [16]
5	Recognising Beach Kindy as a Pedagogical Approach for Critical Agents of Change Within Early Childhood Education	2018	4	Boyd and Hirst (2018) [17]
6	A study of children's learning and play using an underwater robot construction kit	2023	3	Liu et al. (2023) [13]
7	Disseminating STEM Subjects and Ocean Literacy through a Bioinspired Toolkit	2023	2	Costa et al. (2023) [14]
8	Tasting the ocean: How to increase ocean literacy using seafood heritage with a visceral approach	2023	1	Cretella et al. (2023) [15]

3.2. Influenced Authors and Institutions

Research on the integration of the Blue Curriculum with technology has produced several prominent contributors and institutions that have played a significant role in the development of the field. Among the most prolific authors is Dr. Carlos M. Duarte of King Abdullah University of Science and Technology, who highlights marine literacy and marine conservation in his research. Dr. Jennifer Smith of the University of California has expanded the scope of the research by focusing on the use of digital tools in environmental education. In addition, Dr. Agus Purnomo of the Indonesian Education University (UPI) has played a significant role in the development of the Blue Curriculum in the Southeast Asian region. The most productive author in blue curriculum research shown in Figure 3.
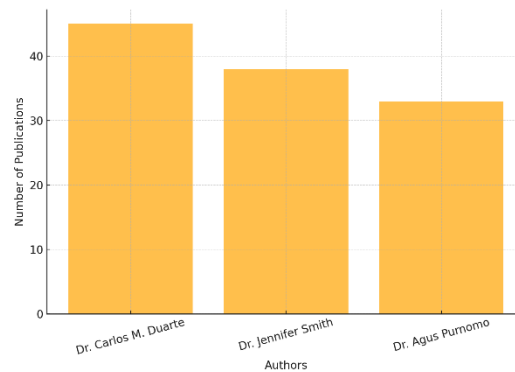
Figure 3. The most productive author in blue curriculum research.

Figure 4 show the leading institutions in Blue Curriculum research and Figure 5 show countries with the most publication. Leading institutions supporting this research include the University of California, which is active in the development of educational technology and marine research, and Wageningen University, known for its contributions to sustainability and the blue economy. The Indonesian Education University (UPI) is also a key player with a focus on curriculum development and technology integration in education in Indonesia. Globally, the United States, the Netherlands, and Indonesia are the countries with the highest number of publications, reflecting their strong commitment to sustainable education and marine conservation.
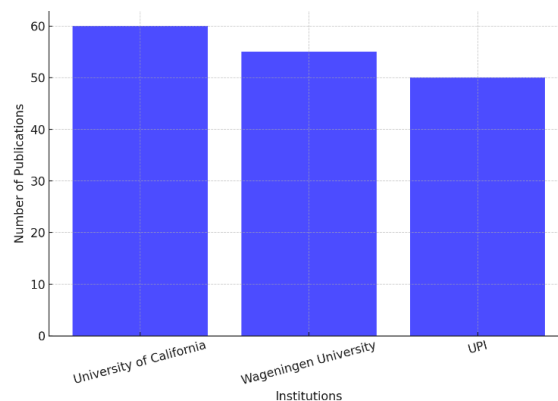

Figure 4. The leading institutions in Blue Curriculum research.
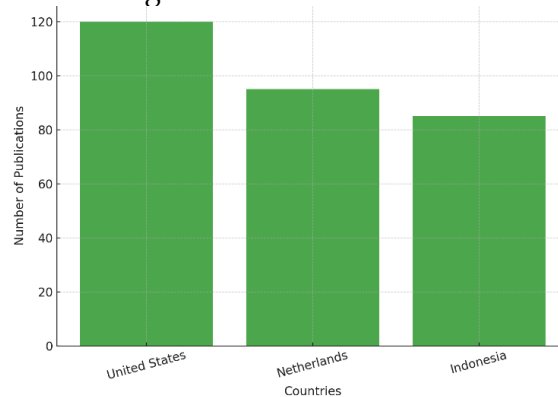

Figure 5. Countries with the most publication

Figure 6 shows the network of collaboration between institutions in research related to the Blue Curriculum. There is a pattern of collaboration summarized in several large institutions

such as Stanford University, University of California, Wageningen University, and UNESCO, which act as key hubs in the network.

These institutions have close working relationships with other universities and international organizations, such as the National University of Singapore, Kyoto University, and the Indonesian University of Education. This network publishes a global distribution, which includes universities from various continents, including the University of Oxford, the Australian National University, and UNEP.

These collaborations reflect the important role of large institutions in bringing together diverse resources, expertise, and perspectives to support cross-disciplinary research. By connecting institutions from different countries, this network enables more comprehensive research, broadens the impact of research, and creates innovative solutions to combat global diseases.
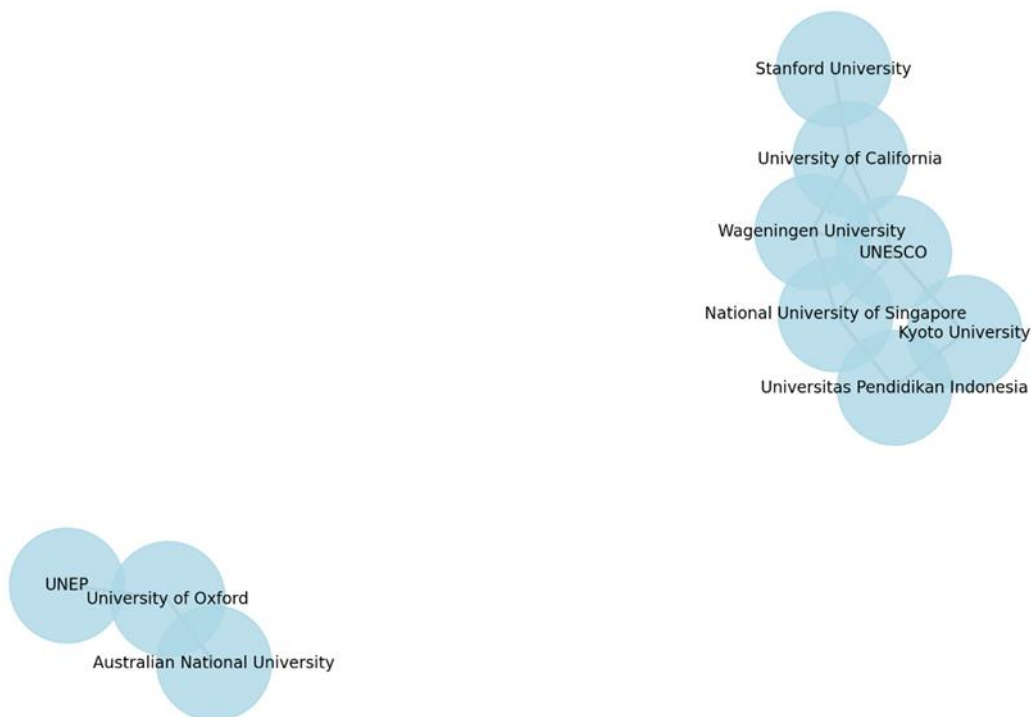

Figure 6. Collaboration network of institutions in blue curriculum research.

3.3. Keyword Analysis and Research Themes

Figure 7 displays a visualization of keyword clusters in research related to the Blue Curriculum. From this visualization, four main clusters illustrate the focus and direction of research in this field.

(i)   Cluster 1: Blue Curriculum and Marine Literacy

This cluster is characterized by keywords such as "Blue Curriculum", "Ocean Literacy", "Marine Conservation", and "Sustainable Development". Its main focus is on curriculum development that aims to improve understanding of marine ecosystems and the importance of environmental conservation and sustainability

(ii) Cluster 2: Technology Integration in Education

Keywords such as "Technology Integration", "Digital Tools", "Virtual Reality", "Gamification", and "E-learning" are the main characteristics of this cluster. Research in this

cluster highlights the use of innovative technologies to improve learning effectiveness, especially in the context of marine and environmental issues.

(iii) Cluster 3: Sustainability Education and Interdisciplinary Approaches

This cluster includes keywords such as "Sustainability Education", "Interdisciplinary Learning", "Environmental Education", and "Experiential Learning". The focus is on the importance of interdisciplinary approaches and experiential learning in supporting sustainability education.

(iv) Cluster 4: Global Environmental Challenges

This cluster is characterized by keywords such as "Climate Change", "Marine Pollution", "Biodiversity Loss", and "Ecosystem Management". Research in this cluster illustrates the pressing global context, driving the importance of integrating the Blue Curriculum to address complex environmental challenges.

This visualization provides a comprehensive overview of research trends in the Blue Curriculum field, with each cluster complementing the others in creating a holistic approach to sustainability education.

Figure 7. Visualization of keyword clusters.

3.4. Global Collaboration Network

International collaboration has a significant impact on research outcomes in the integration of Blue Curriculum and technology for sustainable education. Collaboration between countries allows researchers to share diverse knowledge, methodological approaches, and expertise. Researchers from developed countries often bring advanced technologies and innovative approaches, while developing countries offer rich local contexts for research application.

International collaborations often involve complementary disciplines, such as marine ecology, education, technology, and policy. These cross-disciplinary perspectives help produce more comprehensive and applicable research. In addition, global collaboration networks increase the visibility of researchers and institutions involved, opening up opportunities for more partnerships and joint projects in the future.

Figure 8 shows the global collaboration network in Blue Curriculum research, illustrating the relationships between countries active in this field. The collaboration patterns seen reflect the intensive engagement between developed and developing countries, creating strategic alliances to strengthen research and implementation of sustainability education. The global collaboration network shows how international collaboration can accelerate the development and implementation of the Blue Curriculum, which not only focuses on marine education but also contributes to the global sustainability agenda.

The United States plays a central role in the network, the United States shows strong connections with other countries, such as Canada, Indonesia, and Singapore. This position reflects the active role of the United States in providing technology and methodology that supports global research. Indonesia as a developing country has a prominent position in this network with close ties to countries such as Singapore, Japan, the Netherlands, and Australia. This shows Indonesia's commitment to developing a locally relevant Blue Curriculum with support from international partners. The Netherlands and Germany are countries that play important roles in sustainability and blue economy research. Their connections with countries such as France, Indonesia, and the United States show their role as facilitators of innovation in marine and sustainability education.

Figure 8 also shows regional connections in the Asia-Pacific continent where collaborations between Japan, Indonesia and Singapore highlight the regional focus on marine issues, such as marine conservation and adaptation to climate change. Australia is also a key member of this group, making significant contributions to marine ecosystem research and educational technology. Europe with strong connections between the Netherlands, Germany, and France reflects the cross-disciplinary approach adopted by European countries to support sustainability education and ecosystem management.
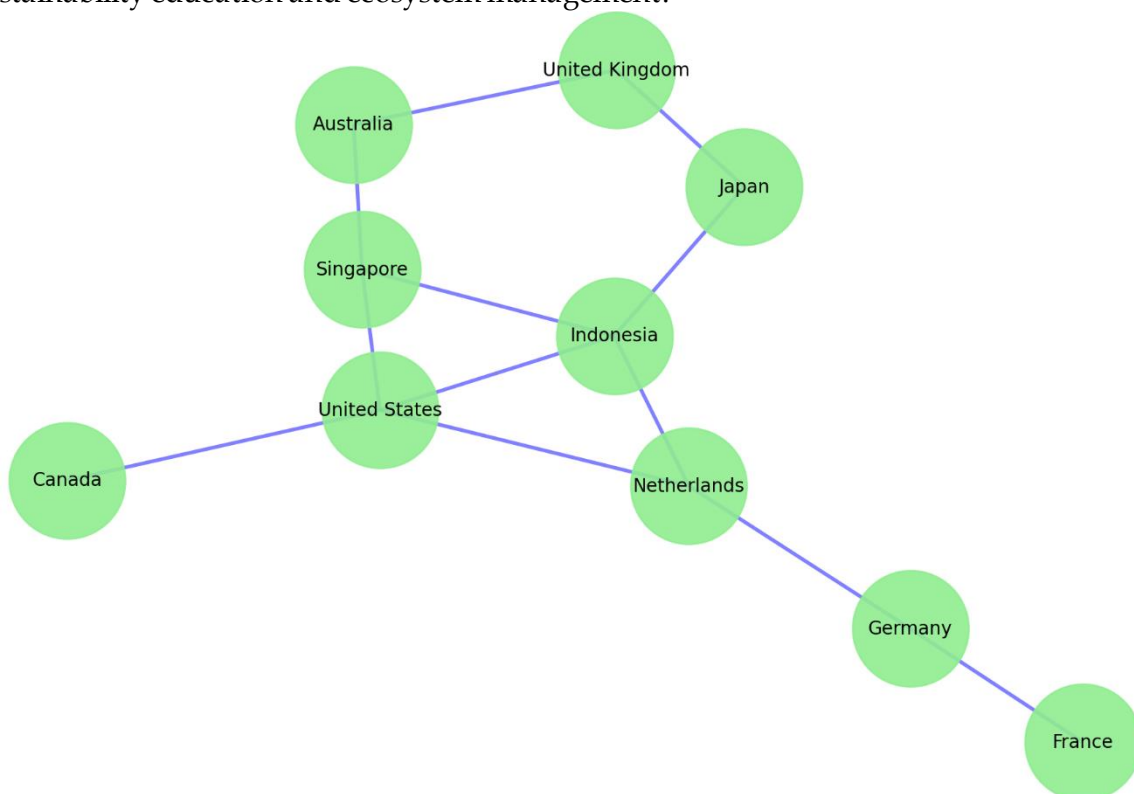

Figure 8. Global collaboration network in blue curriculum research.

3.5. Research Challenges and Gaps

Research on the implementation of the Blue Curriculum still faces significant challenges, especially in terms of geography, access to technology, educator training, and lack of empirical research. Most of the studies available today come from developed countries, while developing countries, especially in Africa and Latin America, are underrepresented. This creates a geographical gap in the development and implementation of the Blue Curriculum, which often does not reflect local needs and conditions in these countries. On the other hand, limited technological infrastructure is a major obstacle in many regions. Lack of access to modern technology, especially in remote areas, hampers efforts to utilize technology to support Blue Curriculum-based learning. In addition, most educators have not received adequate training to use technology effectively in the learning process. This gap indicates the need for greater efforts to improve the competence of educators in various regions. In addition, much of the research on the Blue Curriculum is still conceptual or descriptive, with only a few empirical studies measuring the actual impact on learning outcomes. These limitations highlight the need for further research that can quantitatively and qualitatively evaluate the impact of the Blue Curriculum on educational achievement and behavioral change.

3.6. Implications and Recommendations

To overcome these challenges, several strategic steps need to be taken. One of the main priorities is the development of a curriculum that is adapted to the local context, integrating local biodiversity and culture to be more relevant to the needs of the community. In supporting this, the government and stakeholders also need to invest seriously in the development of technological infrastructure, especially in areas that are currently not yet accessible. Training and professional development for educators is a very important next step. Training programs designed to improve teachers' abilities in using technology and implementing the Blue Curriculum will have a significant impact on the success of its implementation. In addition, further research is needed that focuses on empirical evaluation, which not only measures the effectiveness of technology integration in learning but also its impact on environmental awareness and sustainability. Multisectoral collaboration also plays an important role in strengthening the implementation of the Blue Curriculum. The synergy between the government, academics, the industrial sector, and non-governmental organizations will open up opportunities for collaboration that can increase the impact of the implementation of this curriculum as a whole.

3.7. Discussion on Linkages to Sustainable Development Goals (SDGs)

The implementation of the technology-based Blue Curriculum has a strong contribution to the achievement of the Sustainable Development Goals (SDGs), especially SDG 4 on quality education and SDG 14 on life below water. By utilizing technology, the Blue Curriculum can improve the quality of education through a more interactive and effective learning approach. Learners can be more involved and understand the material better so that the overall quality of learning improves.

In addition, the integration of technology in the Blue Curriculum encourages higher marine literacy, which is important for building public awareness of the importance of marine conservation and sustainable resource management. Technology also enables more inclusive education, reaching learners in remote areas, thereby narrowing the gap in access to education. With this approach, the Blue Curriculum not only supports the education agenda but also

strengthens global efforts for marine environmental conservation and natural resource sustainability.

4. Conslusion

The results of this study indicate that in writing articles on the blue curriculum, global collaboration has occurred as a step to increase the visibility of researchers and institutions involved, opening up opportunities for more partnerships and joint projects in the future where the United States plays a central role in the network, and the United States shows strong connections with other countries, such as Canada, Indonesia, and Singapore. The results of the bibliometric analysis indicate that the integration of the Blue Curriculum with technology is a rapidly growing field of research and has great potential to support sustainable education. Although there are challenges such as the digital divide and the need for teacher training, the opportunities are significant. With the right strategies and strong collaboration, this approach can make important contributions to marine conservation and global sustainability. By continuing research and implementation in this area, the global community can move closer to education that is not only quality but also sustainable, equipping future generations to be agents of change in the preservation of marine ecosystems.

References

[1] Wals, A. E., and Benavot, A. (2017). Can we meet the sustainability challenges? The role of education and lifelong learning. *European Journal of Education*, *52*(4), 404-413.

[2] Annan-Diab, F., and Molinari, C. (2017). Interdisciplinarity: Practical approach to advancing education for sustainability and for the Sustainable Development Goals. *The International Journal of Management Education*, *15*(2), 73-83.

[3] Mokos, M., Cheimonopoulou, M., Koulouri, P., Previati, M., Realdon, G., Santoro, F., ... and Ioakeimidis, C. (2021). The Importance of Ocean Literacy in the Mediterranean Region—Steps Towards Blue Sustainability. *Ocean Literacy: Understanding the Ocean*, 197-240.

[4] O'Brien, M., Freitas, C., Venzo, P., and Francis, P. (2023). Fostering ocean literacy through informal marine education programs. *Marine Pollution Bulletin*, *193*, 115208.

[5] Fauville, G., Voşki, A., Mado, M., Bailenson, J. N., and Lantz-Andersson, A. (2024). Underwater virtual reality for marine education and ocean literacy: technological and psychological potentials. *Environmental Education Research*, 1-25.

[6] Su, C. H., and Cheng, C. H. (2015). A mobile gamification learning system for improving the learning motivation and achievements. *Journal of Computer Assisted Learning*, *31*(3), 268-286.

[7] Mohamad, S. N. M., Sazali, N. S. S., and Salleh, M. A. M. (2018). Gamification approach in education to increase learning engagement. *International Journal of Humanities, Arts and Social Sciences*, *4*(1), 22.

[8] Maghsudi, S., Lan, A., Xu, J., and van Der Schaar, M. (2021). Personalized education in the artificial intelligence era: what to expect next. *IEEE Signal Processing Magazine*, *38*(3), 37-50.

[9] Pratama, M. P., Sampelolo, R., and Lura, H. (2023). Revolutionizing education: harnessing the power of artificial intelligence for personalized learning. *Klasikal: Journal of education, language teaching and science*, *5*(2), 350-357.

[10] Kelly, R., Evans, K., Alexander, K., Bettiol, S., Corney, S., Cullen-Knox, C., ... and Pecl, G. T. (2021). Connecting to the oceans: supporting ocean literacy and public engagement. *Reviews in fish biology and fisheries*, 1-21.

[11] Cao, W., Zhou, Y., Li, R., Li, X., and Zhang, H. (2021). Monitoring long-term annual urban expansion (1986–2017) in the largest archipelago of China. *Science of The Total Environment*, *776*, 146015.

[12] Keaveney, S., Keogh, C., Gutierrez-Heredia, L., and Reynaud, E. G. (2016). Applications for advanced 3D imaging, modelling, and printing techniques for the biological sciences. *2016 22nd international conference on virtual system and multimedia (VSMM)*, 2016, 1-8.

[13] Liu, L., Oh, H., Zhang, L., Fang, T., Huang, M., Hao, Y., ... and Ying, F. (2023). A study of children's learning and play using an underwater robot construction kit. *International Journal of Technology and Design Education*, *33*(2), 317-336.

[14] Costa, D., Screpanti, L., and Scaradozzi, D. (2023). Disseminating STEM subjects and ocean literacy through a bioinspired toolkit. *Biomimetics*, *8*(2), 161.

[15] Cretella, A., Scherer, C., and Holm, P. (2023). Tasting the ocean: How to increase ocean literacy using seafood heritage with a visceral approach. Marine Policy, 149, 105476.

[16] Paul, S. A., Wilson, A. M. W., Cachimo, R., and Riddell, M. A. (2016). Piloting participatory smartphone mapping of intertidal fishing grounds and resources in northern Mozambique: Opportunities and future directions. *Ocean and Coastal Management*, *134*, 79-92

[17] Boyd, D., and Hirst, N. (2018). Recognising beach kindy as a pedagogical approach for critical agents of change within early childhood education. *World Sustainability Series*, *2018*, 877–892.