Biology Learning Based ICT in Indonesia: A Systematic Literature Review

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Abstract: This study aims to identify, analyze, and synthesize key findings regarding the implementation of technology-based biology learning in Indonesia. This study is a Systematic Literature Review (SLR) using the PRISMA model, which includes the stages of identification, screening, eligibility, and inclusion. The data search process utilized search engines and databases such as Google Search, Google Scholar, ResearchGate, SINTA, and Scopus, using keywords related to technology in Biology education. Inclusion criteria for article selection included publications from 2020–2025, experimental articles in English, indexed in SINTA (S1–S2) and Scopus (Q1–Q4), accessible, tested in Indonesia, written by authors from Biology education programs, and thematically relevant. Data analysis was conducted descriptively to identify trends in technology-based Biology learning and to highlight contributions and important information regarding the use of ICT in Biology education in Indonesia. The trend in scientific publications on ICT in Biology education shows positive development with a total of 11 publications between 2020–2025. However, most articles are still indexed in Scopus Q3 and Q4 journals, as well as Sinta 1 and 2. The absence of publications in Scopus Q1 and Q2 journals indicates the challenges faced by Indonesian researchers, such as high writing standards, strict review processes, and a lack of understanding of publication ethics and scientific writing techniques. The use of technology in biology education in Indonesia includes tools such as Lectora Inspire, audio, video, e-books, Zoom, Learning Management Systems (LMS), Digital Mind Maps (DMM), Augmented Reality (AR), Prezi, web-based resources, digital posters, and virtual labs (Gizmos).

Keywords: Biology education; Digital education; ICT; Literature review.

Introduction

Technological developments in the world of education have progressed rapidly compared to the education system itself. As a developing country, Indonesia is striving to utilize technology in its education system. The use of technology in the education system is currently a priority for Indonesia and is considered a solution to conventional education problems. Technological developments have significantly changed the paradigm of education. Therefore, education must be able to respond quickly to these changes to prepare students so they are not left behind in an increasingly digitalized world.

The advantages of technology in education are simplicity and the impact of accessibility and benefits for students and teachers (Ghory & Ghafory, 2021)vv. Through digital platforms, students have the opportunity to learn according to their needs and abilities (Daniela, 2022). According to Wells (2024),

digital-based education can respond to the diverse needs of students, from those with disabilities to those who require enrichment. The use of digital devices can encourage better interaction between students and teachers, enhance the learning experience through interactive tools, and promote innovative thinking, as well as the acquisition of practical knowledge and creativity among students (Radović et al., 2020; Sa'diyah, 2023).

To support the use of technology in the education system, Indonesia has introduced various digital-based programs, including the Merdeka Mengajar platform, the Computer-Based National Assessment (ANBK), and the Education Management Information System. These initiatives aim to ensure equitable digital access for all schools across Indonesia. In addition, it is important to recognize that simply providing access to technology is not enough; there is an urgent need to improve digital literacy and address systemic barriers that contribute to educational inequality (Adeleye et al., 2024; Khalil, 2023).

From a geographical, economic, and technological perspective in Indonesia, it appears that the use of digitalization still faces challenges in achieving inclusive education. Pratiwi (2024) states that many regions in Indonesia still lack digital infrastructure, leading to challenges in implementing digital-based education. Additionally, there remains a significant disparity between regions in terms of access to digital infrastructure. Students in urban areas and from affluent families tend to have access to devices, internet connectivity, and supportive learning environments.

Conversely, students in rural areas or 3T regions (frontier, outermost, and underdeveloped) often face obstacles such as lack of basic facilities like electricity, internet signals, and even digital learning devices. This disparity has the potential to widen the quality gap in education between social groups. Addressing digital disparities must be prioritized to ensure no group is left behind in accessing education in the digital age.

In addition to access issues, teachers and students do not yet have adequate competencies in using technology for learning. This has an impact on the effectiveness of digital learning in the field. Instead of improving quality, the inappropriate use of technology can actually add to the burden and confusion for both educators and students. Without proper intervention, digitization risks becoming merely a symbol of modernization without any substantive impact.

Method

This study is a systematic literature review (SLR). A systematic literature review (SLR) is a process of identifying, evaluating, and analyzing all available information to answer predetermined research questions (Snyder, 2019; Xiao & Watson, 2019). The type of SLR used in this study is Prisma, following the model used by Gallagher et al. (2016), which consists of identification, screening, eligibility, and inclusion (Figure 1). The data in this study are secondary data, namely scientific articles discussing digitalization in biology education.
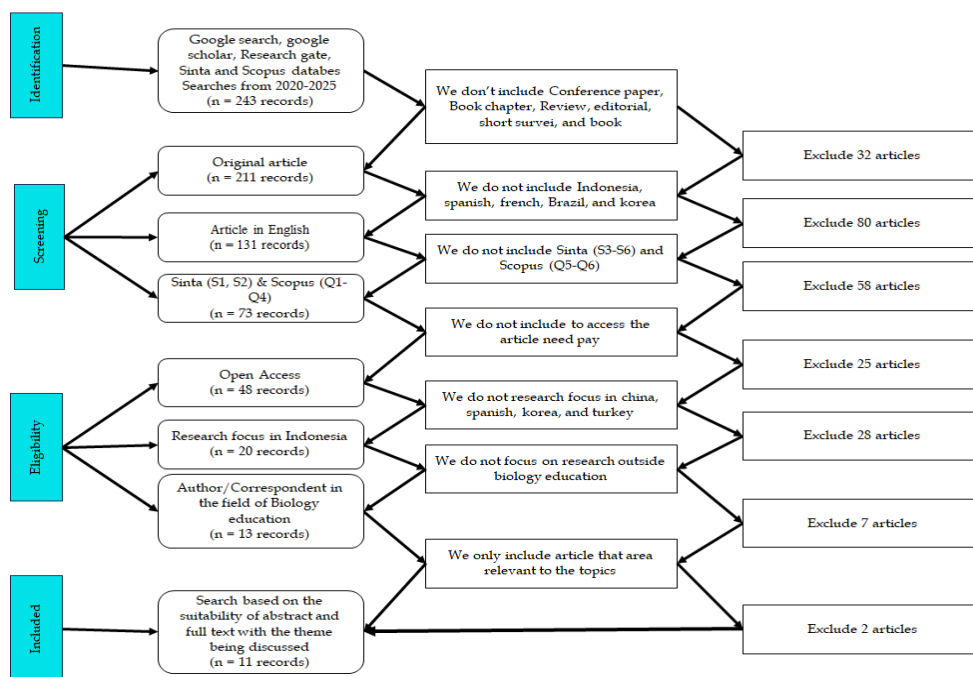

Figure 1. Review process for selection of relevant data

Data collection in this study used search engines consisting of Google Search, Google Scholar, Research Gate, Sinta, and Scopus. The keywords used were: digitalization in biology education, digital learning in biology education, educational technology in biology education, and media-based biology education, e-learning, and digital.

The criteria for selecting data sources in this study include: data used must be from publications between 2020 and 2025; articles based on experiments; articles in English; articles indexed in Sinta (S1, S2) and Scopus (Q1-Q4); articles that are accessible; articles tested in Indonesia; authors or correspondents from biology education programs; and complete articles relevant to the topic.

The data analysis used in this study employed descriptive analysis. Data collected from various sources were analyzed descriptively to identify the main findings of the application of digital learning in biology education in Indonesia, including: trends in digital-based biology education; main findings and implications of the study; an overview of the conditions of digital-based biology education implementation in Indonesia; and journals publishing research on digital-based biology learning reviewed from the Sinta (S1, S2) and Scopus (Q1–Q4) indices.

Results and Discussion

The development of digital technology in the field of education has brought significant changes, including in biology education. In Indonesia, the trend of digital-based biology education has been growing, especially since the emergence of the need for distance learning due to the Covid-19 pandemic. This is in line with the statement by Putri et al. (2020) that biology education has been conducted online since the onset of the pandemic. However, the use of digital technology in biology education still faces challenges, including access to devices and internet quality. Therefore, these issues need to be addressed to ensure the successful implementation of technology in education worldwide (Almusharraf & Khahro, 2020; Casacchia et al., 2021).

Trends in Biology Learning based ICT Publications in Indonesia

A systematic review of 11 publications (Figure 2) that met the research criteria for the period 2020–2025 shows that the use of technology in Biology learning in Indonesia is becoming increasingly diverse and adaptive to the times. Various technologies and digital media such as Lectora Inspire, audio, video, e-books, Zoom, Learning Management Systems (LMS), Digital Mind Maps (DMM), Augmented Reality (AR), Prezi, websites,

digital posters, and virtual labs (Gizmos) have been implemented as tools to create more interactive, flexible, and enjoyable learning experiences (Table 2). This research reflects genuine efforts to enhance the effectiveness of Biology education and align it with the characteristics of the current digital generation.
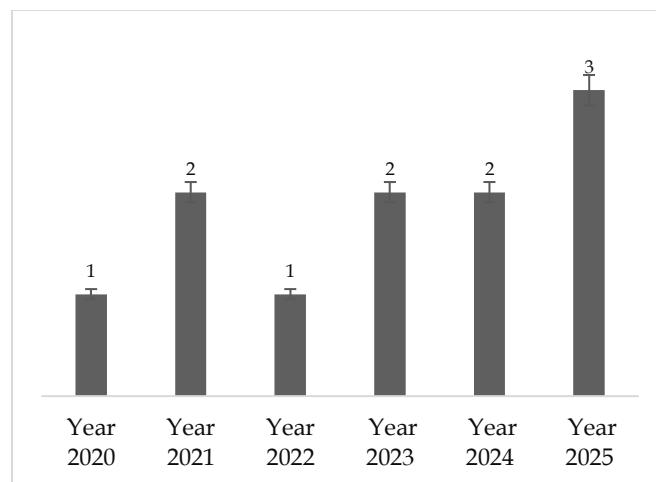

Figure 2. Publication trends on the use of ICT in biology education in Indonesia

The diverse use of technology not only facilitates the learning process but also supports increased student interest and motivation in understanding complex Biology concepts. Additionally, literature indicates that information and communication technology (ICT) can create a more collaborative and student-centered learning environment, enabling students to actively engage in the learning process (Sari et al., 2022). The use of innovative learning models, such as the flipped classroom and problem-based learning, further strengthens the effectiveness of technology utilization in the context of biology learning, enabling students to gain a deeper and more critical understanding of the material being taught (Marhamah et al., 2024).

In addition, it is also known that there are six (6) articles published by three (3) publishers in Sinta-indexed journals with a range of 2 (table 1). From the perspective of quality and distribution of scientific publications, it was found that eight articles were published in Scopus-indexed journals, with six articles in the Q3 quartile and two in the Q4 quartile. This indicates that although the contribution of Indonesian academics is quite significant, there is still room for improvement, especially in reaching journals with higher quartiles such as Q1 and Q2. These publication activities reflect a high level of interest in technology-based research and learning topics, but challenges remain, particularly in terms of meeting established scientific writing quality standards.

Table 1. Research on the use of ICT in biology education in Indonesia

Title, Author	Publisher	Index
The schemes of students' understanding through digital Argumentation in online learning during pandemic covid-19 (Lukitasari et al., 2021)	Journal of education and learning (edulearn)	S1 & Q4
Scientific digital poster assignments: strengthen concepts, train creativity, and communication skills (Wisanti et al., 2024)	International Journal of Evaluation and Researh in Education (IJERE)	S1 & Q3
Effective learning model bases based learning and Digital mind maps to improve student's collaboration skills (Hidayati et al., 2023)		
Guided inquiry with moodle to improve students' science process skills and conceptual understanding (Mursali et al., 2024)		
Scientific literacy-based flipped classroom virtual Strategy for biology learning in the new normal era (Ridlo et al., 2022)	Jurnal Pendidikan IPA Indonesia	S1 & Q3
Stem-based biology learning assisted by virtual lab gizmosTo enhance critical thinking skills of students' With different academic abilities (Jariah, 2025)	Jurnal Pendidikan Sains Indonesia	S2
Analysis of creative thinking skill profiles and learning Recommendations through e-book (Pinareswati, 2025)		
Development augmented reality as a learning media for Sensory system material for class xi in biology learning (Yunita et al., 2025)		
Problem-based learning model with zoom breakout rooms application: Its impact on students' scientific literacy (Priadi et al., 2021)	Online Learning in Educational Research	S2
Development of multimedia learning of cell material in senior High school (Purnamasari et al., 2020)	JETL (Journal of Teaching and Learning	S2
Meta-analysis of the effect of ict-based learning media on Students' biology learning outcomes (Ningsih et al., 2023)		

The lack of articles published in Scopus Q1 and Q2 journals can be attributed to the challenges faced by authors, including high writing quality standards, rigorous peer review processes, and technical and ethical complexities of publication. Many authors in Indonesia still lack understanding of the procedures and ethics of scientific writing, which can hinder their publication process in high-reputation international journals. In the context of research and publication, it is important to understand the ethical aspects of writing to avoid conflicts and misconduct related to writing (Husamah et al., 2022). There is a need to improve the capacity of authors through training and workshops on scientific writing, understanding of international publication standards, and adequate mastery of academic language as an effort to overcome these obstacles.

Therefore, support from higher education institutions in the form of publication training, international research collaboration, and access to reputable journals needs to be enhanced. These steps will contribute to strengthening the existence and quality of research in the field of information and communication technology-based biology learning, as well as encouraging competition and the existence of Indonesian research in an increasingly competitive global arena. Thus, capacity building and structural support are key to facing challenges and taking advantage of opportunities in the current era of educational digitalization (Tiara, 2022).

Based on Table 3, it is evident that the use of Information and Communication Technology (ICT) in Biology education in Indonesia has developed rapidly and has had a significant positive impact on the quality of the learning process and student outcomes. One of the main contributions of ICT is the implementation of multimedia learning, which has transformed the way teachers deliver material to be more engaging and interactive. Research indicates that Biology learning using multimedia can enhance students' interest and motivation by presenting material in an interactive manner, thereby encouraging students to actively engage in the learning process (Julianti et al., 2022; Widiasanti et al., 2023).

Contributions and important information for the use of ICT in biology lessons in Indonesia

The implementation of various innovative learning models combined with technology, such as the flipped classroom and problem-based learning (PBL), has shown tangible results. The flipped classroom model based on scientific literacy in an asynchronous-synchronous-asynchronous approach has proven to enhance student participation and understanding of biological concepts (Waruwu & Sitinjak, 2022). Additionally, research indicates that the use of interactive multimedia in education not only enriches the learning experience but also helps students develop critical thinking and collaboration skills (Wibowo et al., 2021). Similarly, the PBL model utilizing Zoom Breakout Rooms and digital mind mapping has successfully

improved students' science literacy and communication skills (Widiasanti et al., 2023).

Table 2. Trends in ICT use, research methods, and technology-based research barriers in biology education in Indonesia

Author	Technology	Method	Barriers
(Purnamasari et al., 2020)	Lectora Inspire (for developing multimedia learning materials) Multimedia (audio, video, text, images, graphics, animation)	R&D	Students' ability to use Lectora Inspire
(Lukitasari et al., 2021)	argument digital	Qualitative	Not all students have sufficient access to and proficiency in technology.
(Priadi et al., 2021)	Zoom application Breakout Rooms	Quantitative	Students' ability to use technology is still lacking
(Ridlo et al., 2022)	Moodle online learning platform (LMS) Zoom online conference platform with breakout room feature flipped classroom	Qualitative	limited access to technology, internet connectivity, and the adaptation of students and teachers to online platforms and the flipped classroom model.
(Hidayati et al., 2023)	Digital Mind Maps (DMM)	Quantitative	Limitations in mastering DMM technology can hinder the effectiveness of implementation.
(Ningsih et al., 2023)	ICT (Information and Communication Technology)-based learning media such as videos, PowerPoint, interactive multimedia, virtual reality, augmented reality, Adobe Flash animations, Prezi, Flipbook, Google Site-based websites, and HOTs POTATOES crossword puzzles.	Qualitative	Students' digital literacy is still lacking
(Wisanti et al., 2024)	Digital Poster	Quantitative	The time required to prepare and implement digital poster projects can be challenging for students and teachers. Limited access to technology for some students
(Mursali et al., 2024)	Moodle	Quantitative	Challenges in integrating technology in the classroom, especially for students who are unfamiliar with the Moodle platform Limited internet access
(Jariah, 2025)	virtual lab gizmos	Quantitative	limited access to laboratory facilities
(Pinareswati, 2025)	e-book	Quantitative	Students have difficulty developing ideas, processing information flexibly, and elaborating ideas in depth, especially when faced with problems.
(Yunita et al., 2025)	Augmented Reality (AR).	R&D	The process of reading markers by a cell phone camera requires sufficient lighting.

Furthermore, technology supports the mapping of conceptual understanding through digital argumentation and online discussions, which reinforce students' concept revision. Online discussions can reduce anxiety and increase students' confidence in expressing their opinions, which is crucial in the context

of science learning (Khairani et al., 2023). Additionally, the use of technologies such as virtual labs, e-books, and Augmented Reality (AR) further enriches students' learning experiences, particularly for abstract concepts in Biology (Khairani et al., 2023). We reviewed 11 selected articles. Important information from these articles is presented in Table 3.

Table 3. Contributions and important information related to ICT-based research in biology education in Indonesia

Important Information	Reference
Learning multimedia can help teachers in the learning process to create interesting lessons for students .	(Purnamasari et al., 2020)
There was an improvement in every aspect of questioning and answering skills	
Digital argumentation can be used to map students' understanding of scientific concepts.	(Lukitasari et al., 2021)
Students with correct concepts are able to provide logical arguments that support their understanding.	
Conversely, students with incorrect concepts tend to provide inaccurate arguments, and the discussion process helps to reinforce or correct their concepts.	
Online discussions can help reduce anxiety and increase students' confidence in expressing their opinions.	
The PBL model based on Zoom Breakout Rooms has a significant influence on students' science literacy skills.	(Priadi et al., 2021)
The virtual flipped classroom model based on scientific literacy syntax and using an asynchronous-synchronous-asynchronous approach has proven to be effective.	(Ridlo et al., 2022)
It improves students' technological skills and participation, as well as improving their learning outcomes and self-efficacy in understanding biological concepts.	
This model has been appreciated by validators, teachers, and students, and is able to function well in the context of online learning.	
The application of PBL and digital mind maps can improve students' collaboration skills.	(Hidayati et al., 2023)
The use of ICT-based learning media contributes to improving students' learning outcomes in biology.	(Ningsih et al., 2023)
Students demonstrate excellent competence in concept reinforcement, creativity, and communication skills.	(Wisanti et al., 2024)
Technology-assisted inquiry-based learning can improve student learning outcomes.	(Mursali et al., 2024)
STEM-based biology learning aided by virtual lab gizmos significantly improves students' critical thinking skills.	(Jariah, 2025)
Student response to e-book-based biology learning is very good in biology learning	(Pinareswati, 2025)
Augmented Reality (AR)-based biology learning can improve students' understanding.	(Yunita et al., 2025)

Overall, the integration of ICT in Biology education has significantly contributed to the development of students' 21st-century skills, including critical thinking, creativity, communication, and collaboration. These technology-based innovations have received positive feedback from teachers, students, and validators, demonstrating their potential in enhancing the quality of Biology education. Thus, the expansion of interactive multimedia use in the curriculum demonstrates that this approach can improve students' overall learning outcomes, providing a competitive advantage for students in this increasingly digital era (Azizah & Alberida, 2021).

Conclusion

The development of digital technology has had a significant impact on biology education in Indonesia, especially since the Covid-19 pandemic has driven the implementation of online learning. The use of various technology-based media and platforms such as Lectora Inspire, audio, video, e-books, Zoom, Learning Management Systems (LMS), Digital Mind Maps (DMM), Augmented Reality (AR), Prezi, websites, digital posters, and virtual labs (Gizmos) has helped create more interactive and flexible biology learning experiences. However, the implementation of technology still faces challenges such as limited access to devices and poor internet connectivity, which remain major obstacles to the equitable distribution of digital learning. From the perspective of scientific publications, research trends on the use of ICT in biology education show positive development, with a total of 11 publications between 2020 and 2025. However, most articles are still indexed in Scopus Q3 and Q4 journals, as well as Sinta 1 and 2. The absence of publications in Scopus Q1 and Q2 journals indicates the challenges faced by Indonesian researchers, such as high writing

standards, rigorous review processes, and a lack of understanding of publication ethics and the technical aspects of reputable scientific writing. The implementation of ICT-based learning models also contributes to strengthening 21st-century skills such as critical thinking, collaboration, communication, and creativity. Positive responses from students, teachers, and validators to this approach indicate that the use of technology can create a learning environment that is more inclusive, effective, and relevant to the demands of the times.

Author Contributions
This article was written by four authors, namely K.H., W.S., K.S., and M.H.S. All authors worked together at every stage of the preparation of this article.

Conflict of Interest
All authors declare that they have no conflict of interest

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