

Biology Learning Innovation to Support Sustainable Development Program: A Systematic Literature Review (2019-2024)

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Article Info	Abstract
Article history: Received: October 1, 2025 Accepted: February 27, 2026 Published: May 25, 2026 Keywords: Biology learning innovation Literature review Sustainable development program This article is licensed under a Creative Commons Attribution-ShareAlike 4.0 International License. © 2025 Journal of Mathematics, Science, and Computer Education	Learning innovation is one of the important things that must be done in biology learning activities. Learning innovation is also very important to support sustainable development programs, especially for indicators of improving the quality of education. This study aims to analyze the development trend of innovation in biology learning to support sustainable development programs through a literature review. The research method used the PRISMA systematic review approach through a comprehensive literature search from the Google Scholar database. The inclusion criteria in this study were that articles were taken from the Google Scholar database in the period 2019-2024, articles were relevant to the research topic and field of biology, and articles were available in full access, while the exclusion criteria were the opposite of the inclusion criteria. The initial identification resulted in 43 articles, which then went through the evaluation and content analysis stages, resulting in 9 articles. Articles were analyzed based on year of publication, type of innovation, and level of education. The novelty of this article lies in its comprehensive mapping of innovations in biology education with the Sustainable Development Goals (SDGs), as well as the development of an integrative framework that links biology competencies and sustainability competencies. The findings of the literature review revealed that the trend of developing innovations in biology learning increased significantly. Innovation is proven to be able to support sustainable development programs in terms of improving the quality of education and managing environmental sustainability. Learning innovation is dominated by the development of learning resources in the form of teaching materials for students. This finding also shows that the publication of innovation studies has been carried out at various levels of education equally. The contribution of this study is expected to provide recommendations and motivation for teachers to integrate the latest innovations in biology learning activities while supporting sustainable development programs at various levels of education.
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INTRODUCTION

Rapid global development and digital transformation cause changes in various aspects of human life in the fields of education, economy, politics, society, and culture (Fitri et al.,

2025). In the realm of education, global developments are closely related to the use of technology and innovation used in learning in the 21st century (Ariyati et al., 2025). Learning innovation is very important to meet the demands of education in the digital era and globalization, including to optimize the potential of students, provide solutions to real-life problems, and master complex skills (Widyastuti et al., 2020).

Complex skills are abilities that individuals acquire through their involvement in the learning process, including critical thinking, creativity, collaboration, and communication (Manik et al., 2025). Learners are required to be able to reason in order to distinguish ideas clearly, argue well, solve problems, and predict as well as understand complex things more clearly, and are expected to be able to face the demands of the times (Wibawa & Agustina, 2019). The demands of achieving these complex skills certainly force teachers to develop their creativity in the implementation and utilization of learning innovations in the classroom. The successful implementation of learning innovations is highly dependent on teacher readiness and institutional support (Manik et al., 2025; Saptadi, 2025; Tonra et al., 2022). Therefore, needs-based continuous training is an important factor so that teachers have adequate understanding in implementing new learning innovations (Rahman et al., 2023; Wals, 2011).

The massive development of learning innovations indicates the need for 21st-century demands that conventional teaching methods are no longer sufficient for curriculum demands (Fahdluzzakiy et al., 2025; Suwarto et al., 2021). Learning innovations can be developed through the process of integrating technology with project-based learning approaches, as well as the development of 21st-century complex skills (Sadhukhan et al., 2020). Educational content also needs to be packaged innovatively to be relevant and in accordance with the needs of learners to become creative individuals in the future (Zebua, 2025).

The use of technology combined with modern pedagogical approaches plays an important role in creating holistic and flexible learning innovations. Innovation can be inserted through media and learning resources, teaching materials, learning models, teaching activities, and the utilization of cases raised in the classroom (Ekamilasari et al., 2021; Indarini et al., 2025). All these efforts aim to prepare and equip students for future challenges and opportunities (Rahmadi et al., 2025).

The development of the quality of education in Indonesia refers to Law Number 20 of 2003 concerning the National Education System, which states that the development of the quality of education in Indonesia guarantees equitable access, quality improvement, and efficiency of education management in order to create a quality and superior generation (BAPPENAS, 2023). This regulation also states that brilliant innovations that utilize technology wisely are needed to provide access to the digitization of education and can have a positive impact on improving the quality of education in the 21st century to meet the demands of sustainable development (Fahdluzzakiy et al., 2025).

The integration of traditional learning based on local wisdom and modern approaches, such as digital technology, still requires further development. Research focusing on the concrete impact of this approach on science comprehension, critical thinking skills, and attitudes toward sustainability is also limited (Mochizuki & Fadeeva, 2010). Research on how local wisdom can support innovation and preserve local cultural values is still rare. Another gap is the lack of adaptation of local wisdom-based biology learning into the global curriculum, so that its potential to create internationally relevant education has not been fully utilized. Long-term research is needed to evaluate the consistency and sustainability of this innovative approach in supporting sustainable development. Based on this analysis, biology learning based on local wisdom is expected to further enrich learning experiences,

strengthen the relevance of education, and contribute to larger global goals (Saragih et al., 2021).

Efforts to improve and develop the quality of students are aimed at supporting government programs in sustainable development goals (Fahdluzzakiy et al., 2025; Mochizuki & Fadeeva, 2010; Saragih et al., 2021b). The sustainable development goals were first launched by the United Nations in 2015, which include 17 global goals with 169 targets that are expected to be achieved by 2030. Education for sustainable development is often called "Education for Sustainable Development (ESD)," which is in line with sustainable development goal number 4 on quality education (Bappenas, 2021; Kementerian PPN/ Bappenas, 2017).

Quality education that supports sustainable development is very important and attracts the attention of researchers, as well as writers in the 21st century (Fahdluzzakiy et al., 2025). This is evidenced by the increasing trend in the number of publications on the topic of education for sustainable development over the past 10 years. In addition, this topic has also become one of the main nominations in bibliometric analysis (Hallinger & Nguyen, 2020; Prieto-Jiménez et al., 2021). A comprehensive bibliometric analysis is crucial in this study because, although there are many studies related to innovation in biology education, none have examined its relevance in supporting sustainable development (SDGs). In addition, an in-depth study is needed on the critical analysis of the effectiveness of technology-based biology learning models and eco-pedagogy in shaping sustainable action (Rahmawati & Turista, 2025).

Therefore, it is necessary to conduct a systematic literature review to identify various biology learning innovations that have been carried out and assess the trend of implementing learning innovations in the last 5 years at different levels of education. The purpose of this study is to provide in-depth insight into the concept of biology learning innovation to support sustainable development to prepare students for a bright future. In addition, this article also aims to comprehensively map innovations in biology learning with the Sustainable Development Goals (SDGs), as well as the development of an integrative framework that links biology competencies and sustainability competencies.

METHODS

This research included the Systematic Literature Review (SLR) methodology. The SLR methodology is used to find, evaluate, and analyze various studies that are in accordance with certain topics, accompanied by the formulation of relevant problems (Li et al., 2025). The research focus used in the study is innovation in biology learning to support sustainable development programs. The population used in the study was manuscripts from electronic databases (Google Scholar). Google Scholar was chosen for its broad and comprehensive coverage of scientific publications, both nationally and internationally. The literature search was conducted in October 2025 using the keywords "biology learning innovation" and "sustainable development." The guide used in searching and analyzing articles is the PRISMA method (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), which is carried out in stages. The inclusion criteria in this study were that articles were taken from the Google Scholar database in the period 2019-2024, articles were relevant to the research topic and field of biology, and articles were available in full access, while the exclusion criteria were the opposite of the inclusion criteria. According to Liberati et al., (2009). PRISMA consists of four phases, including the following:

1. Identification

The process of searching for article manuscripts based on Google Scholar data and using the keywords "biology learning innovation" and "sustainable development" found 43 articles. The search phase continued with data filtering based on title and abstract. Although

Google Scholar provides extensive literature coverage, a strict selection process is still carried out to ensure that only articles published in accredited journals and that have undergone peer review are included in the analysis.

2. Screening

Articles that have been identified by looking at the relevance of titles and abstracts are then extracted and synthesized. This stage aims to collect information from articles that have passed the selection. Researchers conducted theme categorization, comparative analysis, and concept mapping to produce an in-depth understanding of biology learning innovations that support sustainable development programs. The results of the extraction and synthesis stage obtained 32 articles.

3. Eligibility full text

The eligibility phase is the stage where articles that have gone through the screening process are analyzed for their overall content to determine their eligibility and relevance to the research theme. The research must pay attention to ethical principles, methodological validity, research originality, and relevance to research criteria, and ensure transparency throughout the research process. The final result of this stage was 23 articles. A summary of the article search process is described in Table 1.

Table 1 Summary of the article search process

Inclusive	Exclusive
Journals retrieved from Google Scholar	Journals outside Google Scholar
2019-2024 timeframe	Beyond the 2019-2024 timeframe
Articles do not contain citations	Articles contain citations
In accordance with the filled of study of biology	Field of study other than biology
Not including thesis	Thesis
Open access	Closed access

4. Included

The number of articles that have passed eligibility was identified, reviewed, analyzed, and evaluated. The aim is to ensure that only quality journals are used in this study. The results of the SLR synthesis were a recommendation for researchers to examine new insights into the development of innovations in biology learning to support sustainable development programs, develop a better framework for managing education and teaching, and identify areas that require further research. In this phase, nine articles were obtained from the initial 43 articles, which were then analyzed in depth. The expected output is to be able to provide theoretical contributions to the development of future biology learning innovations. The flowchart of activities carried out in this study is shown in Figure 1.

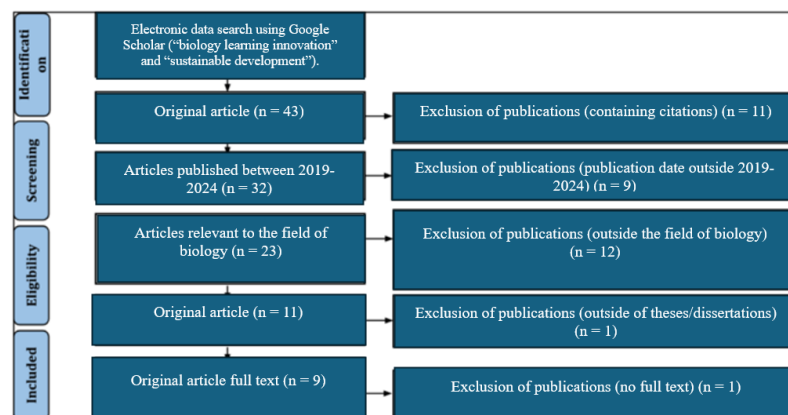


Figure 1 Article selection process in SLR studies using the PRISMA model

RESULTS AND DISCUSSION

Publication trends

This literature review was conducted on 9 selected articles that were the result of screening from the initial 43 articles. Article screening was conducted through the Google Scholar database. The inclusion criteria used in this study are biology learning innovations to support sustainable development programs. The publication of articles is limited to the range of 2019 to 2024. The analysis of the literature review on biology learning innovation research to support sustainable development programs through the PRISMA method can be seen in Figure 2.

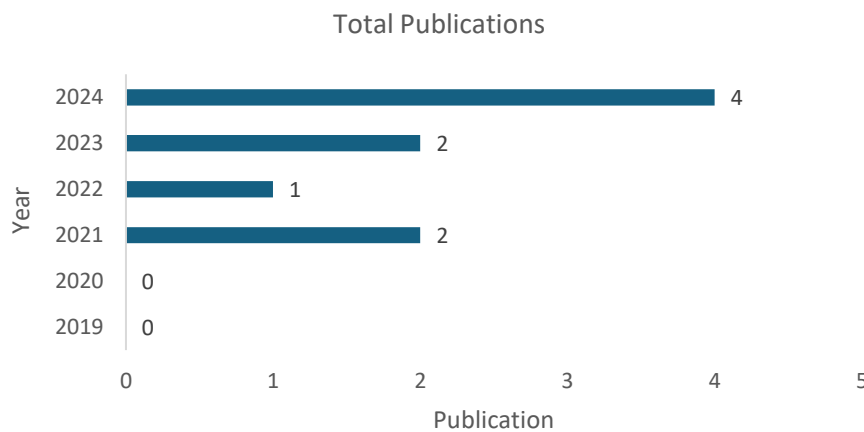


Figure 2 Distribution of research by year of publication

Based on the results of research distribution from 2019 to 2024, it shows variations from year to year. In 2019 and 2020, there were no article publications. In 2021 and 2023, there were 2 articles each related to the research topic, while in 2022, there was only 1 research article. The peak, namely in 2024, was recorded as the year with the highest number of publications, namely 4 articles. This shows that there is an increasing need for teachers to develop digital learning innovations that are up to date today ([Zulhafizh & Permatasari, 2020](#)). Another factor that can cause a shift in learning methods in the 21st century is the demand for teachers to design biology learning that is creative and in accordance with the interests of students ([Antika et al., 2022](#)).

The limited number of articles included in this study is due to several factors. Firstly, the use of narrowly defined keywords during the literature search in the Google Scholar database may limit the breadth of relevant studies retrieved. Secondly, access to full-text articles was limited, as not all identified publications were available in full. Thirdly, this study only used one database, Google Scholar, which may have excluded other potentially relevant studies in other databases. Finally, the strict application of inclusion and exclusion criteria further narrowed the selection of eligible articles.

Various findings of biology learning innovations to support sustainable development programs

Learning innovation can determine the achievement of students' learning objectives, as well as support sustainable development programs. Based on the literature review selection process, 9 articles met the criteria and were analyzed further. The results of the analysis were classified into three main categories, namely author name, title, and research findings. A summary of the article results is outlined in Table 2.

Table 2 Findings of articles based on the selection process

No	Author	Title	Findings
1	Sintia et al. (2021)	Validitas buku ilmiah populer tumbuhan aren (Arenga pinnata Merr.)	The popular science books developed are highly effective in enhancing the learning experience of learners of a certain age and education level.
2	Bariroh et al. (2024)	The potential of the malabot tumpe ethnobiology-containing e-module in realizing sustainable biodiversity conservation	E-modules that integrate Malabot Tumpe local wisdom can improve sustainable skills in terms of public awareness and collaboration in biodiversity conservation efforts and provide meaningful learning experiences.
3	Soenarno (2024)	Pendidikan konservasi alam merupakan sebuah Pendidikan karakter	Teaching materials that integrate local wisdom can foster literacy, build the character of students who care about the environment, and prepare individuals to utilize natural resources wisely for sustainable development.
4	Azizi & Muttaqin (2021)	Pengaruh pembelajaran mini riset berbasis kearifan local terhadap penguasaan materi dan analisis permasalahan konservasi lingkungan	The local wisdom-based mini research learning model significantly improves mastery of biology concepts, attitudes, and skills on nature conservation and can promote sustainable development at the high school level.
5	Ermin (2022)	Hubungan keterampilan metakognisi, kemampuan berpikir kritis dan sikap social siswa SMP di Kota Ternate terhadap retens pada mata Pelajaran IPA	The metacognition skill assessment rubric can determine the relationship between the importance of critical thinking and social attitudes in improving understanding and retention of biological material in junior high school students.
6	Iwan et al. (2024)	The effect of PBL integrated with igya ser hanjob's local wisdom to improve students' problem-solving skills in conservation biology courses	PBL learning model combined with local wisdom knowledge can significantly improve problem-solving skills in the topic of conservation biology in students
7	Erfariyah et al. (2024)	Development of conservation e-books based on local potential to improve eco-literacy of junior high school students	Local potential-based conservation e-books improve environmental literacy in the aspects of attitudes, skills, and human relationships with nature among junior high school students. In addition, the e-book can also improve critical thinking skills.
8	Rozilawati (2021)	Pengembangan jiwa bioentepreneurship dan jaga lingkungan pada mata Pelajaran biologi untuk siswa menengah atas di era pandemik covid	The collaborative online learning method of biotechnology through projects is able to build entrepreneurial spirit, practice entrepreneurial skills, and provide environmental education for sustainability in high school.
9	Aini et al. (2023)	Pengembangan komik sains terintegrasi literasi lingkungan pada topik mitigasi bencana banjir	The development of integrated science comics can improve the environmental literacy of MTS students to mitigate flood-prone areas.

Based on the literature review, it can be seen that the use of learning innovations in the classroom can provide support for sustainable development programs through literacy activities, learning experiences, social skills, and fostering public awareness of nature conservation. Biology learning innovation combined with local wisdom can be a sustainable conservation effort (Bariroh et al., 2024; Erfariyah et al., 2024). This is certainly very important to realize the 15th SDG goal, especially the biodiversity material. The integration of traditional knowledge and technology can provide easy and fun access to sustainable biodiversity conservation efforts (Bariroh et al., 2024; Kerdlap et al., 2019).

Biology learning innovations that support sustainable development emphasize the integration of Education for Sustainable Development (ESD) into the curriculum and learning practices. Learning is designed to improve students' ecological literacy, critical thinking skills, and environmental awareness through contextual methods such as problem-based learning, project-based learning, and the use of digital technology. Integrated digital technology, such as conservation e-books, can improve environmental literacy and is effective in learning (Erfariyah et al., 2024). Environmental literacy can be integrated with the development of science comics. Comics are a fun learning medium and present material in the form of illustrated stories. Comics give a relaxed impression and are easy to understand, so it is hoped that students will not be bored reading the material (Aini et al., 2023).

The characteristics of biology learning that have content very close to life are expected to provide solutions to environmental problems. One solution that can be offered by biology is simple food biotechnology. The concept of the material is packaged with a simple practicum of making products so that it can be practiced at home. In addition, this activity is able to take advantage of business opportunities and instill the character of environmental care by integrating daily activity evaluations in the E-module (Rozilawati, 2021). Learning is structured around real-world cases that integrate sustainability issues into biological material, enabling students to understand scientific concepts and apply solutions to global sustainability challenges such as climate change and ecosystem degradation. Research or projects that are often carried out in biology activities can improve the ability to analyze problems to solve biological issues, as well as show changes in students' attitudes and behavior towards nature in order to create sustainable development (Azizi & Muttaqin, 2021; Untari et al., 2023).

Learning innovation can also be done by developing assessment rubrics. The relationship between critical thinking skills and social attitudes can be assessed through a metacognition skills assessment rubric. This rubric can also assess students' understanding and retention of biological material (Ermin, 2022). The results of the analysis show that the integration of local wisdom with media and learning resources is one of the important factors in the development of learning innovations. Integration of learning with local wisdom can foster an attitude of literacy, build the character of students who care about the environment, and prepare individuals to utilize natural resources wisely for the success of sustainable development (Soenarno, 2024). The various benefits that can be obtained from the development of learning innovations make many researchers suggest the development of other innovations with more complete applications and features (Wals, 2011).

Distribution of research at different levels of education

In addition to the annual distribution, research classification is also carried out based on the grade level that is the target of research on biology learning innovations to support sustainable research programs. Based on the level of education, the publication of biology learning innovations to support sustainable development programs is evenly distributed at each level of education. Details of research distribution by class are presented in Figure 3.

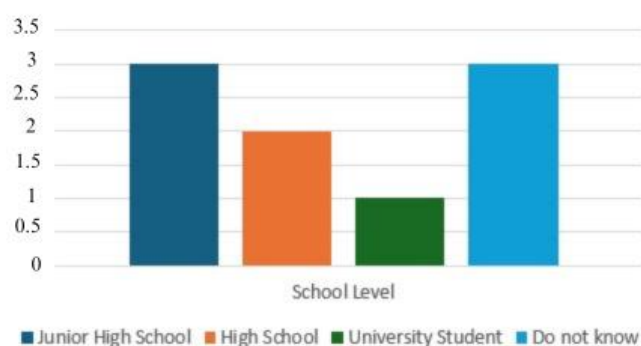


Figure 3 Distribution of research by class

Figure 3 Distribution of research by class

Figure 3 shows that the development of biology learning innovations to support sustainable development programs is evenly distributed at every level of education. Based on the results of the analysis, it can be seen that the importance of developing learning innovations in the classroom is at every level of education. Strategic steps that can be taken to improve the application of innovative learning, namely improving teacher competence through continuous training, utilizing resources optimally, taking a flexible approach to determine needs, and considering the conditions of students so that learning can be effective (Nurvianti et al., 2025; Putra et al., 2025).

Forms of learning innovations

Apart from being studied based on class and year of publication, the results of the article analysis also found that there are differences in the form of learning innovations developed. This analysis aims to determine the trend of the most widely used forms of innovation in biology learning. Details of the distribution of types of learning innovations can be seen in Figure 4.

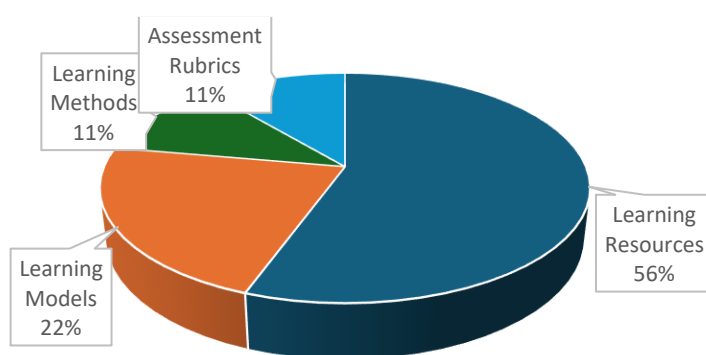


Figure 4 Distribution of learning innovation types

Based on the review, learning innovation through the development of learning resources is the most developed in research, with a total of five articles. Next, the learning model is 2 articles. Other innovations that are also developed, namely integrated learning methods and the development of assessment rubrics, appear with less frequency, namely 1 article each. The development of learning resources is the most widely used form of learning

innovation due to the limitations of existing learning resources. These results provide an initial picture of the tendency of researchers in choosing the type of biology learning innovation to support sustainable development programs ([Mulyaningsih et al., 2025](#); [Saptadi, 2025](#)).

Limited learning resources can be caused by the condition of the students' area and the absence of a needs analysis in the area. The development of innovative renewable teaching materials that integrate various media, models, and learning approaches can train students' critical thinking skills ([Chordnork & Yuenyong, 2014](#); [Wardhono et al., 2024](#)). The selection of teaching materials that are innovated with learning models and approaches can help achieve more optimal learning outcomes in students ([Bujuri et al., 2022](#)). The preparation of types of learning resources must pay attention to the suitability of the characteristics of teaching materials with the learning outcomes to be achieved ([Chan & Nagatomo, 2022](#); [Ie et al., 2025](#)).

Innovations in biology education are increasingly geared toward developing 21st-century skills, such as critical thinking, collaboration, communication, and problem solving, as well as connecting learning to global issues through the Sustainable Development Goals (SDGs). Recent research confirms the dominance of effective learning approaches and models in strengthening 21st-century skills while raising awareness of sustainability ([Rahmawati & Turista, 2025](#)). The link between biology learning and Education for Sustainable Development (ESD) to integrate sustainable principles into the learning process can be achieved through the selection of learning models that address environmental issues and environmental literacy ([Siregar et al., 2024](#)). Innovative learning models (PBL, inquiry, and discovery learning) actualize constructivist learning theory because they enable students to play an active role in building knowledge through problem-solving and exploration. This model is also close to the collaborative approach that is in line with the socio-constructivist theory relevant to environment-based projects ([Karmana, 2024](#)). The integration of learning innovation with sustainability not only improves understanding of biology content but also shapes students' global competencies for a generation capable of facing environmental and social challenges ([Gurning & Selaras, 2025](#)).

CONCLUSION

This systematic review concludes that the trend of research on biology learning innovation to support sustainable development programs has experienced significant growth over the past 5 years. Publication trends covering this topic show a diversity of research at various levels of education, ranging from junior high school, high school, and university. The innovations developed are also very diverse, ranging from learning resources and learning models to assessment rubrics. This study emphasizes that the development of biology innovations plays a very important role in supporting sustainable development programs to prepare students for a bright future. The mapping of SDG-oriented biology learning innovations strongly supports the strategic position of biology learning because these innovations are key instruments in the implementation and support of the SDGs with discussions on environmental issues, life, health, and ecosystem sustainability. Further research recommendations suggest increasing publications on similar topics to determine the impact of biology learning innovations that support sustainable development programs at the primary and early childhood education levels. Additionally, it is necessary to analyze the relevance of AI-based innovations, such as Augmented Reality/Virtual Reality (AR/VR), to expand concept exploration and support students' interest in learning to embrace the future.

CONFLICTS OF INTEREST

The authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS STATEMENT

Conceptualization: UR; methodology: ZFA; data collection: OP and HF; formal analysis RO; original drafting: UR and NA; reference collection: ZFA and OP.

AI DISCLOSURE STATEMENT

The authors used Canva during the preparation of this work for design images and graphics. After using the tool/service, the author thoroughly reviewed and edited the content as needed and takes full responsibility for the content of the publication. The authors declare that this research was prepared, researched, written, and edited without the aid of artificial intelligence (AI) techniques.

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