JPPIPA 11(10) (2025)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Environmental Education Strategies for Supporting Sustainable Waste Management: a Systematic Literature Review

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Received: January 31, 2025
Revised: September 05, 2025
Accepted: October 25, 2025
Published: October 31, 2025

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DOI: 10.29303/jppipa.v11i10.10550

Abstract: The study identifies and synthesizes strategies used in environmental education programs aimed at improving waste management behavior through a Systematic Literature Review (SLR) using the Scopus database. The analysis highlights three widely applied strategies: project-based learning, which engages students in recycling and conservation projects; experiential learning, which emphasizes real experiences for deeper understanding; and community-based training, which empowers communities to apply environmental knowledge in daily life. These strategies are often integrated with dialogic processes and digital media (e.g., blogs, animated videos, worksheets) to enhance environmental awareness and sustainable practices. The findings confirm that these approaches effectively increase understanding, awareness, and community participation in waste management. This study reinforces the importance of targeted environmental education in driving behavioral change and serves as a reference for designing sustainable environmental programs.

Keywords: Environmental Education; Learning Strategies; Waste Management

Introduction

The United Nations (UN) in the United Nations of Environment Programme reports that the environment is experiencing increasing damage from year to year. The damage that occurs is partly caused by the rapid increase in population because of the increasingly dense human population, especially coupled with an increase in irresponsible lifestyles for the environment, one of which can increase the production of waste (Global Footprint Network, 2021; Sakti et al., 2021; UNEP, 2021).

The United Nations Environment Program (UNEP) reported that in 2022, the world produced around 2.24 billion tons of waste per year. The production of waste, which has increased significantly in recent decades, impacts the increasing challenges in waste management. In line with this, *The World Bank Group* (2018) estimates that the global waste volume will increase to 3.4 billion tonnes by 2050 unless effective and intensive action is taken to address waste management problems.

The increase in global waste volume can be a severe threat to the sustainability of the ecosystem, considering the large amount of waste that is not appropriately managed, such as waste that ends up in landfills, oceans, and open environments. Waste that is not managed correctly can later cause air, water, and soil pollution and increase greenhouse gas emissions (Kaza et al., 2018).

Effective waste management can positively impact the environment, reduce the use of new resources, and reduce carbon emissions from waste processing and disposal. Critical steps in waste management include reducing waste at source, such as separating waste from source, improving recycling infrastructure, and

How to Cite:
Ningrum, I. H., Tohani, E., & Sugito. (2025). Environmental Education Strategies for Supporting Sustainable Waste Management: a Systematic Literature Review. *Jurnal Penelitian Pendidikan IPA*, *11*(10), 133–142. https://doi.org/10.29303/jppipa.v11i10.10550

circular economy policies. The European Environment Agency (2020) states that effective waste management can increase recycling rates by up to 50% and reduce the amount of waste sent to landfill. However, waste management behavior at the individual level still needs to improve, especially in developing countries (Massoud et al., 2021; Rousta et al., 2020). Therefore, effective interventions are needed to increase awareness and pro-environmental behavior in society.

Environmental education has long been recognized as an essential tool for encouraging behavioral change concerning changing behavior to protect the environment. Environmental education aims to increase individuals' understanding of environmental issues and motivate them to take responsibility for their behavior toward the environment in which they live. The Intergovernmental Panel on Climate Change (IPCC) (2021) emphasizes that effective education can increase individuals' awareness of environmental issues and motivate behavioral change. A recent study by Swiattkowski et al. (2024) also showed that well-designed environmental education programs positively and significantly impact an individual's pro-environmental attitudes and behavior.

Guided environmental education refers to programs designed with clear structures and objectives. Guided Environmental Education aims to provide practical knowledge and skills to change individual behavior. Environmental education that focuses on waste management education has been widely implemented. This is shown by Previous studies have shown that targeted environmental education can significantly improve waste management behavior, as shown in the study of Fallah-Nejad et al. (2023), it was found that environmental education can improve waste sorting behavior, but Tanjung et al. (2024) identified that other factors, such as the availability of facilities and perceived behavioral control can influence whether awareness and positive attitudes can be implemented in real action. In addition, Sumartan et al. (2023) highlighted the importance of education in increasing participation, but could not directly discuss the challenges or obstacles in its implementation.

In general, research efforts on waste management have been carried out a lot, but are still specific and fragmentary. This shows that there needs to be a more comprehensive and complex approach to assess the impact of environmental education programs on waste management that have been implemented. A *systematic literature review* offers a method of synthesizing findings from various studies by providing a more transparent and complex picture of waste management.

Systematic literature review research on environmental education has been widely conducted, including environmental education for the community, which is limited to waste management counseling activities (Apriliani et al., 2024), a review of organic waste management in educational institutions (Freitas et al., 2023) and environmental awareness education in public administration practice (Kuswandy et al., 2024). Thus, this study aims to systematically review the existing literature to identify and synthesize findings regarding the strategies/approaches and media used as well as the results of environmental education programs that are directed at waste management behavior.

Method

This research is a literature review research that refers to the use of the Systematic Literature Review (SLR) method. Systematic Literature Review in this study was used to collect, identify, and analyze available research studies on strategies used in environmental education programs and their impacts through systematic procedures that produce a comprehensive review of the available scientific evidence (Carrera-Rivera et al., 2022; Pati & Lorusso, 2017; Xiao & Watson, 2017).

Literature Review research, according to (Han et al., 2020; Husamah et al., 2022), has five stages, including (1) formulating research questions functions to define the scope and develop the focus of the research, thus facilitating the collection and identification of relevant articles so that the research is more focused. This study focuses on strategies, media, and results of environmental education on changes in waste management behavior by the community; (2) Formulating research targets involves searching, selecting, assessing, and compiling a list of articles related to the research questions, using the Scopus database because it provides credible articles with multidisciplinary coverage and rapid updates (Falagas et al., 2008) using the keywords "environmental education" and "waste management" limited to articles published in 2021-2024; (3) Selecting and Evaluating Data Findings by determining inclusion and exclusion criteria, inclusion criteria include topics, discussions according to research focus, limited to full text and open access journal articles, so that points outside these criteria are exclusion criteria; (4) Analysis and Synthesis is the following process of treating articles that have been selected according to the inclusion criteria; (5) Reporting of results is a conclusion of the overall research results. The stages in literature review research are presented in Figure 1.

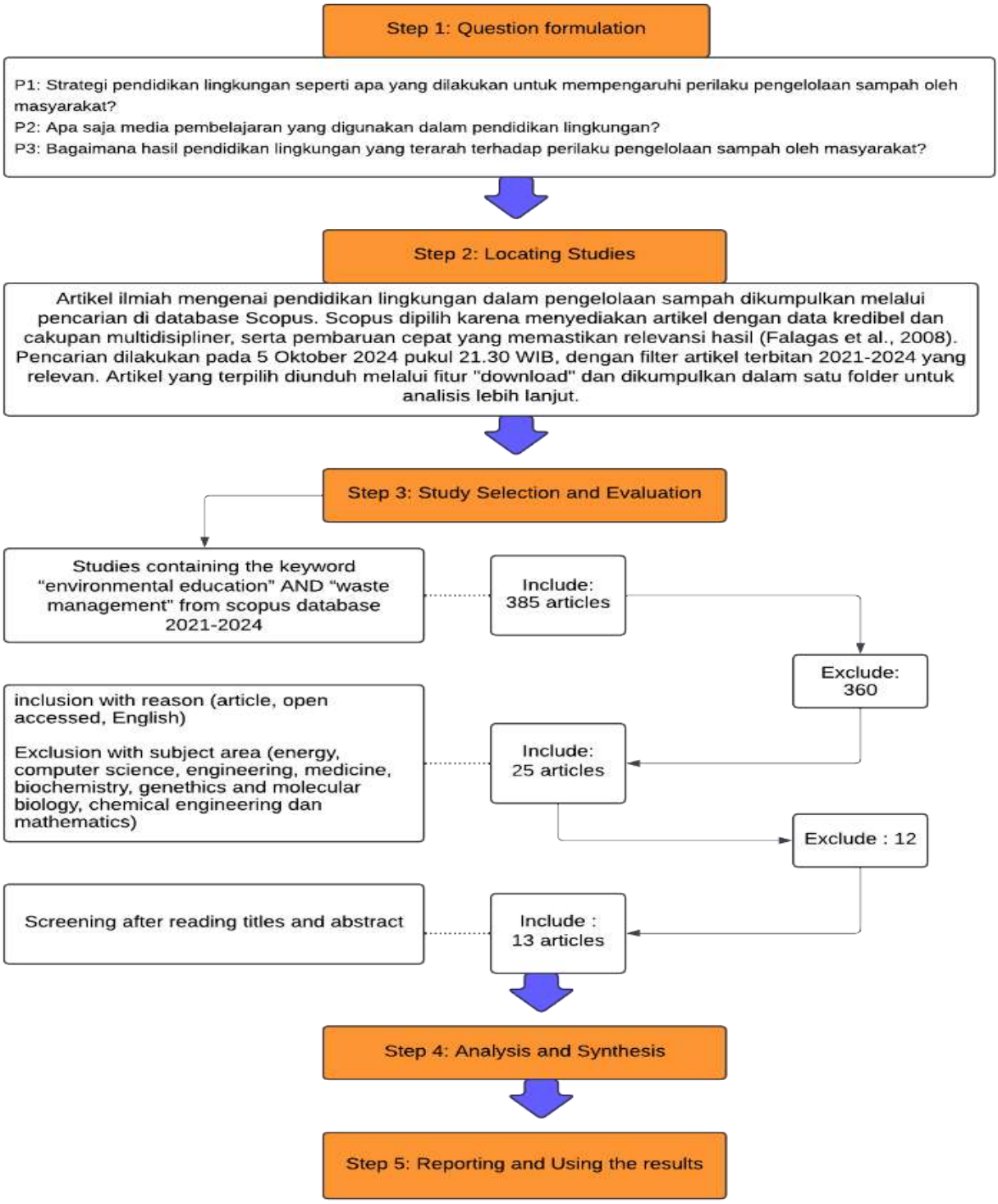

Figure 1. Stages of Systematic Literature Review, adapted from (Han et al., 2020)

Result and Discussion

The selection process successfully obtained 13 relevant articles focusing on environmental education strategies and their impact on waste management behavior. The selected articles were from the period 2021-2024 and covered a variety of environmental education strategies implemented in various countries and contexts, the analysis of the article findings is presented in Table 1.

Table 1 Analysis of article findings based on research questions

Article Title	Writer	Research methods	Environmental Education Strategies and Media	Educational Outcomes
A Community Project on Waste Management Awareness and Livelihood Training of Residents Nearby a Polluted Creek: An Impact Study	(Edullantes et al., 2024)	Mix method	Community-based environmental education through training on waste sorting, recycling, and reusing so that waste has value.	There has been an increase in the community's knowledge, attitudes, and practices regarding waste management, significant waste reduction, and increased community involvement in environmental cleanliness.
Blog as a Pedagogical Strategy to Enhance Learning About Household Solid Waste	(Boesing & De Campos Lopes, 2023)	Qualitative	Using blogs as a pedagogical technology tool to teach household waste management.	Improve students' understanding of waste management; demonstrate active involvement and a sense of responsibility towards the environment through content.
Classification of Urban Solid Waste Collected with the Use of Ecobarriers in Watercourses in the Municipality of Caapava do Sul, RS	(Kemmerich et al., 2023)	Experiment	Environmental education on the importance of using eco-barriers for waste management in waterways.	It reduces the volume of waste that pollutes rivers and increases public awareness of waste management in waters.
Nurturing Eco-Literate Minds: Unveiling the Pathways to Minimize Ecological Footprint in Early Childhood Education	(Friman et al., 2024)	Evaluation study	Implementation of the "Green Ambassadors in the Community" program, which instills ecological awareness in early childhood through experiential learning and consequence monitoring.	They are increasing environmental awareness and reducing ecological impacts by improving children's competence in sustainable practices by promoting their knowledge to others.
The Impact of a Rural School-Based Solid Waste Management Project on Learners' Perceptions, Attitudes and Understanding of Recycling	(Mkhonto & Mnguni, 2021)	Quantitative, quasi-experimental	Integrated waste management project in independent practice activities with interventions, focusing on waste separation and recycling processes.	Participating in a project improves perceptions, attitudes, and understanding of recycling.
A Zero-Waste Campus Framework: Perceptions and Practices of University Campus Communities in Malaysia	(Baba-Nalikant et al., 2023)	qualitative	Discussion	We are increasing environmental awareness, forming pro-environmental behavior, and developing promotional instruments for zero-waste attitudes among students.
Can Coral Reef Restoration Programs Facilitate Changes in Environmental Attitudes? A Case Study on a Rural Fisher Community in North Bali, Indonesia	(Boakes et al., 2023)	Qualitative	Environmental education through coral reef restoration programs that involve local communities in waste management and ecotourism education.	Positive changes in people's environmental attitudes, increased support for waste management, and the emergence of new environmental regulations have occurred.
Environmental Education in Children: 3R Practices in Boboiboy Animation	(Mamat et al., 2024)	Qualitative	Boboiboy animation is used to teach children the concept of 3R (Reduce, Reuse, Recycle) through animated series.	Increasing children's awareness of the importance of waste management and environmental values through fun and easy-to-understand education.
Analysis of the Development of Environmental Culture and Mathematical Skills for Solid Waste Management in Schools	(Lopera et al., 2024)	Qualitative	Combining environmental education with mathematical skills through solid waste management programs in schools with dialogic and experiential learning	Increasing environmental awareness of students and their families regarding waste management and developing mathematical skills in the actual context of waste management.

Article Title	Writer	Research methods	Environmental Education Strategies and Media	Educational Outcomes
			processes.	
Raising Awareness on Solid Waste Management through Formal Education for Sustainability: A Developing Countries Evidence Review	(Debrah et al., 2021)	Systematic Scientific Literature	Formal education in schools and colleges, focuses on reducing the environmental knowledge gap between students and the community.	Students and teachers are becoming increasingly aware of environmental issues, although practical knowledge about waste management is still lacking. Formal education in developing countries plays a vital role in changing attitudes and behaviors about waste management.
Concept of Circular Economy in Technical and Vocational Education: A Systematic Literature Review	(Hamid et al., 2024)	Systematic Literature Review	integration of the circular economy concept in vocational education, including waste management through the *reduce, reuse, recycle* (3R) approach.	It increases students' competency and awareness regarding sustainable resource management, especially in food systems and waste management.
Environmental Perception of Solid Waste Management in the Hurtado Balneary, Colombia	(Vargas et al., 2024)	Survey and Observation	Environmental education related to waste management in tourist areas, including installing signage for river conservation.	Raising awareness about waste management and reducing waste dumped into rivers
Factors Influencing Environmental Awareness and Solid Waste Management Practices in Bogotá: An Analysis Using Machine Learning	(Henao-Rodríguez et al., 2024)	Quantitative	Environmental education program with a focus on waste separation and improving waste management infrastructure.	Increased waste separation in certain areas that have better access to recycling facilitiesC

Environmental Education Strategies that Influence Community Waste Management Behavior

Environmental education is essential in encouraging changes in community behavior regarding sustainable environmental management. Targeted environmental education needs to be provided to all levels of society and various levels of education to reduce the gap in knowledge about waste management between communities (Debrah et al., 2021; Hamid et al., 2024). The results of the analysis of the articles on environmental education above indicate various learning strategies used in the implementation of environmental education as an effort to increase public awareness and involvement in environmental issues. The learning strategies used in the implementation of environmental education vary, some of the strategies used include Project-based learning (Boakes et al., 2023; Boesing & De Campos Lopes, 2023; Henao-Rodríguez et al., 2024; Kemmerich et al., 2023; Vargas et al., 2024), experiential learning (Friman et al., 2024; Lopera et al., 2024; Mkhonto & Mnguni, 2021), and community-based training (Edullantes et al., 2024).

One widely used strategy is project-based learning, which uses projects/activities as the primary media of the educational process. Project-based learning emphasizes the activeness of students or the community in gaining knowledge through real experience/action through various individual and collaborative activities that aim to solve problems and apply them in the form of certain authentic products (Jayanti & Pertiwi, 2023; Puspitasari et al., 2024). This strategy emphasizes direct practice and actual interventions such as participation in recycling projects or nature conservation actions, which can strengthen people's understanding of the direct impact of their actions on the environment so that their active involvement in real action can generate an awareness of the importance of individual contributions in protecting the environment (Boakes et al., 2023; Boesing & De Campos Lopes, 2023; Henao-Rodríguez et al., 2024; Kemmerich et al., 2023; Vargas et al., 2024).

In addition, experiential learning is also used in the environmental education process. Experiential learning is one of the exceptionally effective strategies (irfianti, 2016) in implementing environmental education (Friman et al., 2024; Lopera et al., 2024; Mkhonto & Mnguni, 2021). This strategy emphasizes experiences where people interact directly with the environment, not just passively accepting theory (Hayati, 2020). Direct experience is a starting point for

community empowerment, connecting experience with theoretical concepts. Through this, the knowledge gained can be internalized properly.

Experiential learning was born from Kolb's theory, which provides an opportunity for the community as participants to experience concepts directly to gain a richer and more meaningful understanding (Hayati, 2020). Kolb describes the experiential learning cycle in four stages: concrete experience, abstract conceptualization, observation and reflection, and active experimentation, which can be started at any stage. They function as information input at the concrete experience and abstract conceptualization stage. At the same time, observation, reflection, and active experimentation require reflection on experience and suggestions for future actions based on reflection results. Thus, using experiential learning in environmental education is the right step because it can facilitate the community's opening of their eyes to the surrounding nature, which can later increase their acceptance of environmental reality (Hayati, 2020).

Furthermore, Community-based training is also used to implement environmental education in waste management (Edullantes et al., 2024). Community-based training is a process of empowering people or communities to develop skills and resources to support the fulfillment of their needs, and this approach strategy is often used in the context of waste management (Imam Rosadi, 2020). Community-based training focusing on waste sorting and recycling has increased knowledge, attitudes, and waste management practices among local communities and reduced unmanaged waste. This approach aims to empower people through the knowledge they gain to be applied in their daily lives so that environmental awareness at the local level can be created (Edullantes et al., 2024).

The three strategies above are often implemented using dialogic methods (Boakes et al., 2023; Edullantes et al., 2024; Lopera et al., 2024). The dialogic method transfers knowledge with a liberating approach to foster innovation and creativity in individual knowledge of the reality around them (Widianingsih, 2021). This strategy invites the community to participate in an open discussion or dialogue regarding environmental issues so a more dynamic and participatory exchange of ideas emerges. If open dialogue is successful, a more contextual and inclusive solution to environmental challenges will be born (Baba-Nalikant et al., 2023). Combining the dialogic process with environmental education strategies, such as experiential learning, shows that the community gains practical experience and reflects on their experiences through in-depth dialogue (Lopera et al., 2024). This combination can provide more holistic results and can build a more prosperous and inclusive conceptual understanding of their waste management problems.

Learning Media in the Implementation of Targeted Environmental Education

Learning media is used in implementing environmental education through various approaches and strategies. Learning media is a means that helps transfer knowledge so that the learning process runs effectively (Muhaimin & Juandi, 2023). There are types of media used in the implementation of environmental education strategies, including digital learning, some of which utilize animated videos (Mamat et al., 2024), blogs (Boesing & De Campos Lopes, 2023), and presentation videos (Lopera et al., 2024) for the learning process, as well as the use of worksheet media that is adjusted to the curriculum of the institution or related subjects (Debrah et al., 2021; Mkhonto & Mnguni, 2021).

Digital learning is an effective alternative to delivering the content of a learning material and can contribute significantly to creating a fun learning experience in various types of learning (Fitri & Hadi, 2024; Wityastuti et al., 2022). The use of technological advances that are also utilized in education through the use of digital media include the use of blogs as a pedagogical technology tool to teach household waste management to promote waste management content so that it can be read widely and have an impact on increasing awareness of the importance of household waste management (Boesing & De Campos Lopes, 2023). The use of animated videos such as Boboyboy, which discusses the importance of protecting the environment, is quite adequate, especially if the audience is children because it can encourage active involvement and increase a sense of responsibility for the environment (Mamat et al., 2024). In addition, a study shows that the use of animated media accompanied by spoken text and simulations accompanied by written text obtains better learning outcomes than animation without text or simulations (Kleftodimos, 2024; Lopera et al., 2024).

Worksheets are one of the learning media or teaching materials that effectively encourage individuals to think more critically and function to minimize educators' role in activating students (Sungkono & Wulandari, 2021). Worksheets are often used for evaluation activities or reflection of learning outcomes and make learning more structured and interactive (Sumarmi et al., 2021). Worksheets must go through proper and intensive monitoring and direction because if not, especially for independent or distance learning activities, the use of worksheets could be more

effective (Mkhonto & Mnguni, 2021). However, its use can effectively reduce knowledge gaps regarding the environment if the worksheets are prepared according to the existing material and conditions and with clear directions (Debrah et al., 2021).

Results of Environmental Education Directed towards Waste Management Behavior by the Community

Targeted environmental education programs consistently show positive results on waste management behavior, increasing knowledge and reducing waste in the community. Targeted environmental education programs have provided significant results on waste management by the community such as the emergence of new regulations and support for waste management from both the community and local government (Boakes et al., 2023), increased waste sorting and recycling facilities (Henao-Rodríguez et al., 2024), decreased volume of waste polluting rivers (Kemmerich et al., 2023) and increased awareness not to throw waste in rivers (Vargas et al., 2024). One of the main results is increased community knowledge about waste management (Boesing & De Campos Lopes, 2023; Edullantes et al., 2024; Friman et al., 2024; Lopera et al., 2024; Mamat et al., 2024).

The community better understands the importance of waste sorting, recycling, and sustainable waste management through environmental education, thus forming environmental awareness (Immaniar et al., 2019). Methods involving integration Studies conducted by Edullantes et al. (2024) showed that community-based training successfully improved community knowledge and practices in waste management, ultimately contributing to unmanaged waste reduction.

In addition, environmental education can also change people's attitudes toward environmental issues (Labobar & Kapojos, 2023; Mkhonto & Mnguni, 2021). Project-based learning programs, such as those implemented in the coral reef restoration project in Bali by Boakes et al. (2023), showed increased community awareness and support for the cleanliness of their environment. Communities involved in this program began to show a more proactive attitude in managing waste, especially in coastal areas vulnerable to waste pollution. Other studies have also shown that project-based learning can improve understanding of waste management and community environmental attitudes and participation (Ayu et al., 2023; Puspitasari et al., 2024).

The results of environmental education programs show a decrease in the volume of waste polluting the environment, especially in areas with direct educational interventions (Kemmerich et al., 2023; Vargas et al., 2024). An example of the success of project-based learning is the use of eco-barriers (Kemmerich et al., 2023) as part of environmental education in Brazil and the installation of signage (Vargas et al., 2024), which successfully reduced the amount of waste polluting the river. This proves that using project-based strategies in implementing environmental education in waste management can have a concrete impact on environmental quality.

Integration of targeted environmental education with other sciences, such as mathematics learning (Lopera et al., 2024) through direct experience, can increase environmental awareness (Irfianti et al., 2016) and reduce ecological impacts (Friman et al., 2024). However, if the implementation is not accompanied by inadequate learner motivation, ineffective team collaboration, and an imbalance in didactic instructions and research result collection methods, it can affect learning outcomes in an undesirable direction (Mkhonto & Mnguni, 2021).

Environmental education also plays an essential role in shaping waste management policies. Some institutions, such as universities and schools, have started to adopt zero-waste policies after implementing environmental education programs. For example, a study by Baba-Nalikant et al. (2023) showed that a Malaysian university engaged in environmental education successfully created a zero-waste framework. The program encouraged students to be more actively involved in reducing waste generation and increasing recycling on campus.

Overall, targeted environmental education has succeeded in changing people's behavior regarding waste management. In addition to increasing public knowledge and awareness, this program also encourages the active participation of individuals and community groups in maintaining environmental cleanliness and reducing the volume of waste that pollutes public areas. This shows that targeted environmental education is an effective instrument for creating sustainable behavioral changes in society.

Conclusion

Environmental education's implementation often uses various learning strategies including project-based learning, experiential learning, and community-based training. All three are often collaborated with dialogic activities and the help of learning media such as blogs, animated videos, and worksheets. In addition, in project-based learning, practical tools such as the installation of signage and eco barriers are used in the education processconclusion is presented briefly,

narrative and conceptual which describes the research findings and its impacts. Please avoid using bullets.

Author Contributions
Intan Hayun Ningrum, wrote the introduction, methods, results, discussion and conclussions. Entoh Tohani and Sugito, guidance during research and manuscript writing.

Funding
Research funding is funded by researchers independently.

Conflicts of Interest
There is no conflict of interest related in this research.

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