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Exploring Strategies to Promote Waste Management in Education for A Sustainable Future: A Systematic Literature Review

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Abstract: As the global community faces escalating environmental challenges, integrating waste management into educational curricula is essential for fostering sustainable practices among future generations. By equipping students with the knowledge and skills to understand the impact of waste, we empower them to take active roles in promoting environmental stewardship and advocating for responsible consumption. This article presents a systematic literature review exploring effective strategies for promoting waste management in educational settings, framed within the context of Education for Sustainable Development (ESD). The PRISMA 2020 systematic literature review method was used, with Scopus as the primary database. Out of 761 collected articles, 20 met the criteria for thematic-qualitative analysis. By synthesizing findings from a range of studies, this article identifies key themes and successful models that enhance student awareness and action regarding waste management. The insights gained contribute to a deeper understanding of how ESD can effectively shape waste management practices, ultimately supporting the development of a sustainable future. This work highlights the critical role of education in cultivating environmentally responsible behaviors and encourages educators to adopt innovative strategies that align with ESD principles.

Abstrak: *Seiring meningkatnya tantangan lingkungan yang dihadapi masyarakat global, integrasi pengelolaan sampah ke dalam kurikulum pendidikan sangat penting untuk mendorong praktik berkelanjutan bagi generasi mendatang. Dengan membekali siswa dengan pengetahuan dan keterampilan untuk memahami dampak sampah, kami memberdayakan mereka untuk berperan aktif dalam mempromosikan pengelolaan lingkungan dan mengadvokasi konsumsi yang bertanggung jawab. Artikel ini menyajikan tinjauan pustaka sistematis yang mengeksplorasi strategi efektif untuk mempromosikan pengelolaan sampah di lingkungan pendidikan, yang dibingkai dalam konteks Pendidikan untuk Pembangunan Berkelanjutan (PPB). Metode tinjauan pustaka sistematis PRISMA 2020 digunakan, dengan Scopus sebagai basis data utama. Dari 761 artikel yang dikumpulkan, 20 artikel memenuhi kriteria analisis tematik-kualitatif. Dengan mensintesis temuan dari berbagai studi, artikel ini mengidentifikasi tema-tema kunci dan model-model sukses yang meningkatkan kesadaran dan tindakan siswa terkait pengelolaan sampah. Wawasan yang diperoleh berkontribusi pada pemahaman yang lebih mendalam tentang bagaimana PPB dapat secara efektif membentuk praktik pengelolaan sampah, yang pada akhirnya mendukung pengembangan masa depan yang berkelanjutan. Karya ini menyoroti peran penting pendidikan dalam menumbuhkan perilaku yang bertanggung jawab terhadap lingkungan dan mendorong para pendidik untuk mengadopsi strategi inovatif yang selaras dengan prinsip-prinsip PPB.*

INTRODUCTION

In recent years, global environmental concerns have increasingly spotlighted the urgent need for sustainable waste management, particularly within educational institutions. Every year, billions of tons of waste are generated worldwide, with predictions showing a continued rise due to consumption-driven societies and rapid urbanization (Smith et al., 2022; Huang and Zhao, 2023). This upsurge in waste generation and limited capacity for landfilling call for immediate action toward sustainable and circular waste management solutions (Garcia et al., 2020; Lopez et al., 2022). Schools are essential in driving these changes. Research has shown that food waste persists in school catering services, indicating that additional incentives are needed to encourage ongoing reductions in food waste (Cohen et al., 2013). With their diverse populations, sizes, and various activities, educational institutions function like small communities and have a significant potential to influence sustainable waste practices. Furthermore, while 821 million people face hunger and 3 billion cannot afford a nutritious diet, food waste continues to be a problem (Chu et al., 2023). This wasted food also contributes to 8% to 10% of global greenhouse gas emissions. The issue of food waste in schools reflects not only nutritional imbalances among students but also the problem of partial eating (Cohen et al., 2013). As a result, food waste has considerable environmental, social, and economic consequences.

A sustainable approach to waste management is essential for addressing global environmental, social, and economic challenges (D'Souza et al., 2021; Ali et al., 2023). The circular economy model works synergistically with sustainable development, promoting closed-loop systems where resources are managed thoughtfully to minimize waste and negative environmental impacts while fostering economic resilience and social welfare (Ricci and Silva, 2019; Tanaka, 2023). In this context, educational institutions serve as ideal platforms for implementing these strategies, aligning their waste management practices with the Sustainable Development Goals (SDGs) established by the United Nations. As noted by UNECED (1992), education is vital for fostering sustainable development and empowering individuals to tackle environmental and developmental issues, which has led to the creation of the concept known as Education for Sustainable Development (ESD).

ESD is an idea that embeds sustainability into the thoughts, emotions, and behaviors of future generations (Zguir et al., 2021). It is described as "a process that fosters the development of knowledge, skills, understanding, values, and actions necessary to create a sustainable world that guarantees environmental protection, promotes social equity, and supports economic sustainability" (Gamage et al., 2022). UNESCO's ESD framework beyond 2019 focuses on enhancing ESD's contribution to achieving all 17 Sustainable Development Goals (SDGs), with an emphasis on policies, learning environments, teachers and educators, youth, and communities (UNESCO, 2019). Specifically, SDG 12, which emphasizes responsible consumption and production, underscores the significance of sustainable waste practices in advancing the global agenda for environmental health and sustainability (United Nations, 2015).

By promoting waste minimization and fostering a culture of sustainability, they can be central to global efforts for sustainable waste management and increased awareness among future generations (Jones et al., 2015; Kumar et al., 2023). Today's school should be able to provide a good environment in the sense of a healthy and comfortable environment for the learning process in it (Utama et al., 2018). School is no longer a place to learn, but also serves for recreational areas such as sports and arts activities. Education efforts should focus on raising awareness and providing information about waste management practices (Pisuttu et al., 2024). Therefore, the waste management becomes very important in the management of school in general.

Research on the implementation of waste management in schools has been widely conducted. One such study by Debrah (2021) on raising awareness on solid waste management revealed that awareness alone is not sufficient to drive behavior change. Another study by Singseewo (2016) examined the effectiveness of curriculum-based environmental education with a focus on waste management. The findings showed that students' awareness significantly improved after participating in environment-focused lessons. However, these improvements were

short-term and limited to knowledge, awareness, and participation. Therefore, to truly promote sustainable waste management practices, it is essential to integrate actionable learning experiences and consistent teacher guidance. This can be more effectively achieved through the implementation of ESD in classroom activities—a dimension that remains underexplored in previous research.

This study aims to explore various strategies to promote effective waste management in education, emphasizing a sustainable future. In pursuit of this objective, the research poses the following question: What are the strategies to promote effective waste management in education? To comprehensively grasp the strategies inherent in this pedagogical approach, a thorough analysis of existing empirical research is imperative. Through an extensive literature review, we identify actionable strategies that educational institutions can adopt to encourage waste reduction, improve resource efficiency, and instill sustainable behaviors. These insights are intended to serve as a valuable resource for the scientific community in expanding waste management research and for educators and administrators who are directly responsible for creating impactful, sustainable initiatives within educational settings.

METHOD

The study utilized a Systematic Literature Review (SLR) following the PRISMA 2020 guidelines (Page et al., 2021) to examine prior research and gather information on the implementation of STEM-ESD learning. The search was conducted on October 7, 2024, using Scopus as the primary database due to its credibility, provision of high-quality information, ease of data retrieval, and relevance to the study's focus.

Keyword employed in the searches is “waste management education”. The initial search yielded 761 articles. These articles were then screened based on their titles, abstracts, and full-text content according to the criteria outlined in Table 1. This screening process aimed to identify the most relevant studies for in-depth analysis to understand the opportunities and challenges of implementing STEM-ESD learning.

Table 1. Eligibility Criteria

No	Inclusion Criteria	Exclusion Criteria
1	Article published between 2020 and 2024	Published before 2020
2	Text in the form of journal articles or proceedings	The title is not in English
3	Journal indexed by Scopus (Q1-Q4) or Sinta (S1-S2)	The article or proceeding is not empirical research
4	Related to waste management education research	Not related to waste management education research

To ensure a structured selection process, the researcher utilized Microsoft Excel to facilitate data coding, sorting, and analysis. Out of 761 articles, 741 were eliminated because they did not meet the predetermined criteria. The detailed procedure of the selection process is illustrated in Figure 1.

Based on the selection results, there were 20 articles that met the criteria. The analysis of these articles involved a meta-synthesis approach which included several stages: (1) identification of the research focus; (2) identification of relevant research; (3) selection of research that meets the review criteria; (4) assessment of the selected research; (5) extraction of data from the research; and (6) synthesis of data. This approach is in accordance with the methodology proposed by Evans & Pearson (2001). The selection of this method is not only because it provides a structured guide in conducting this research, but also because it is relevant to the main purpose of the study, which is to analyze and synthesize various previous studies related to waste management education. This will result in comprehensive information about the strategies to promote waste management in education for a sustainable future.

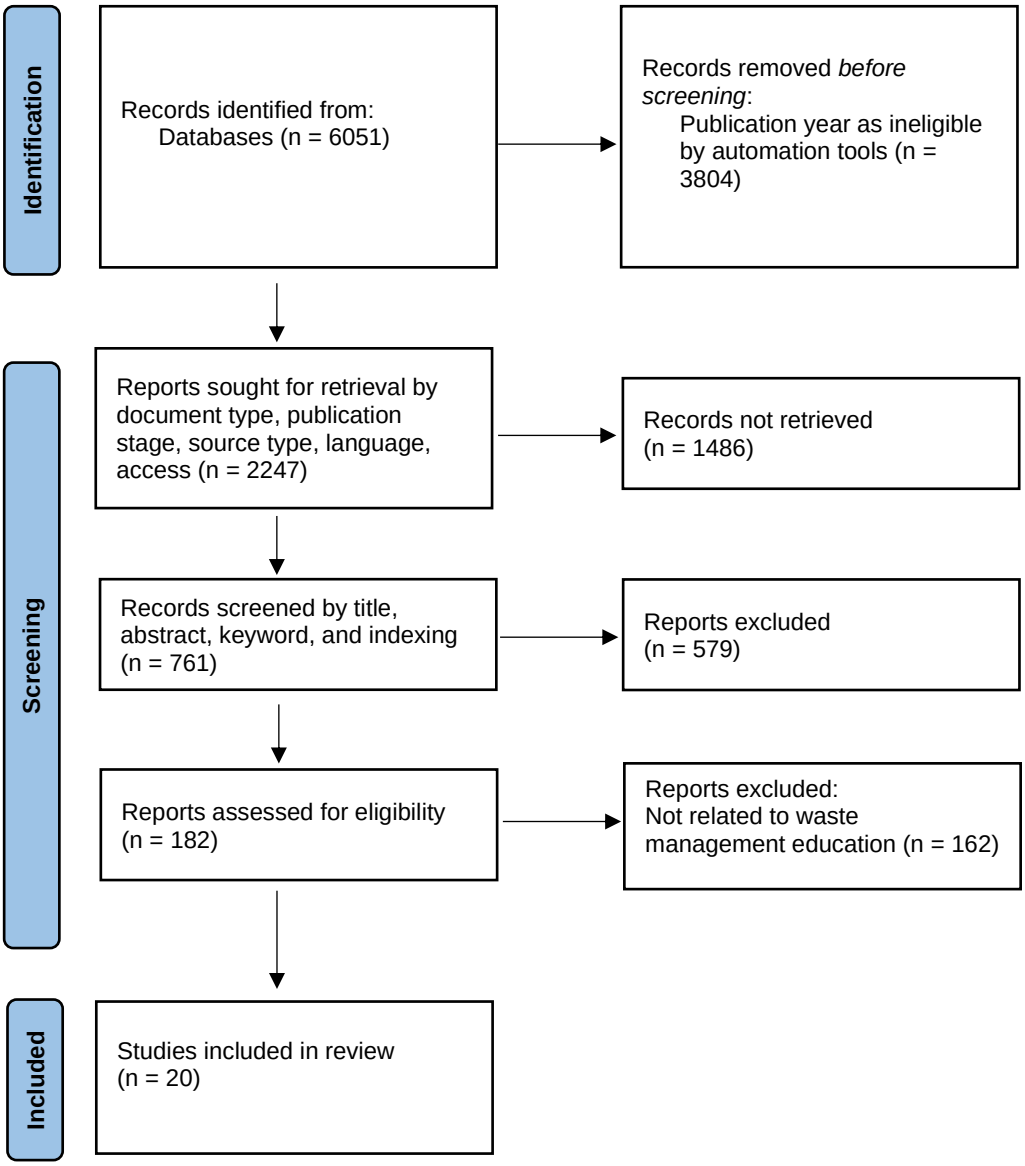

Figure 1. Article Selection Flow Diagram

RESULTS AND DISCUSSION

Effective waste management is essential for fostering environmental awareness and responsibility among students. Schools should implement comprehensive planning programs that engage students in practical waste management activities (Filho et al., 2024; Saseanu et al., 2019). The strategies to promote waste management in education can be seen in the following Table 2.

Table 2. The strategies to promote waste management in education

No	Strategies	Author
1	Integrating Sustainability into Curriculum	(Chu et al., 2023; Dayaday & Galleto, 2022; de Jager, 2015; Elnakib et al., 2024; García-Fortes et al., 2024; Hidayati et al., 2021; Owojori et al., 2022; Pardal et al., 2020; Pisuttu et al., 2024; Saseanu et al., 2019)
2	Planning Waste Management Programs	(Budihardjo et al., 2021; Cahyanti et al., 2019; Catalano et al., 2024; Chu et al., 2023; Dayaday & Galleto, 2022; Filho et al., 2024; Giurea et al., 2024; Musicus et al., 2022; Owojori et al., 2022; Rada et al., 2016; Rahmawati et al., 2017; Utama et al., 2018)

3	Action-Oriented Approaches	(Cahyanti et al., 2019; Catalano et al., 2024; de Jager, 2015; Elnakib et al., 2024; García-Fortes et al., 2024; Giurea et al., 2024; Hidayati et al., 2021; Musicus et al., 2022; Owojori et al., 2022; Rada et al., 2016; Rahmawati et al., 2017; Saseanu et al., 2019)
4	Awareness Campaigns	(Budihardjo et al., 2021; Catalano et al., 2024; Choi et al., 2022; Chu et al., 2023; Dayaday & Galleto, 2022; Filho et al., 2024; Giurea et al., 2024; Hidayati et al., 2021; Musicus et al., 2022; Owojori et al., 2022; Pardal et al., 2020; Rada et al., 2016; Rahmawati et al., 2017; Saseanu et al., 2019; Utama et al., 2018)
5	Community Engagement	(Cahyanti et al., 2019; Catalano et al., 2024; Choi et al., 2022; Dayaday & Galleto, 2022; de Jager, 2015; Elnakib et al., 2024; Filho et al., 2024; Giurea et al., 2024; Hidayati et al., 2021; Owojori et al., 2022; Pisuttu et al., 2024; Rada et al., 2016; Saseanu et al., 2019)
6	Teacher Training	(de Jager, 2015; Filho et al., 2024; García-Fortes et al., 2024; Hidayati et al., 2021; Pardal et al., 2020; Rada et al., 2016)

1. Integrating Sustainability into Curriculum

Educational institutions should incorporate sustainability and waste management topics into their curricula to enhance students' understanding and skills related to environmental protection (Saseanu et al., 2019). Educational programs should focus on changing behaviors related to food consumption and waste (Filho et al., 2024). This includes integrating sustainability into the curriculum and encouraging students to engage in sustainability initiatives. Integrating sustainability can help students understand the importance of sustainable practices and their role in promoting a circular economy (Owojori et al., 2022).

In Education for Sustainable Development (ESD), there are 17 goals of SDGs. Specifically, SDG 12, which emphasizes responsible consumption and production, underscores the significance of sustainable waste practices in advancing the global agenda for environmental health and sustainability (United Nations, 2015). This alignment can guide institutions in developing relevant waste management strategies (Owojori et al., 2022).

Programs should integrate sustainability goals into their curricula, encouraging students to become agents of change (Pisuttu et al., 2024). This approach helps students understand the interconnectedness of these issues and encourages sustainable behaviors (Elnakib et al., 2024). This can foster a culture of sustainability and environmental stewardship within the academic community (Dayaday & Galleto, 2022). Integrating sustainability concepts into curricula can lead to well-trained graduates who are equipped to address sustainability challenges in their professional lives.

2. Planning Waste Management Programs

Schools should implement comprehensive planning programs that engage students in practical waste management activities (Filho et al., 2024; Saseanu et al., 2019). Establish a comprehensive waste management system that includes proper waste segregation, recycling facilities, and composting infrastructure (Giurea et al., 2024). This system should cover all areas of the school area, including classrooms, laboratories, offices, libraries, kitchen and cafeteria and student residences. Establishing systems for recycling and composting can help manage waste effectively (Filho et al., 2024). Schools can set up specific bins for selective waste collection and explore converting waste into renewable energy sources, such as biogas. Besides, school can set up composting facilities on campus for organic waste generated from dining halls, food courts, and gardens. This infrastructure is crucial for encouraging students to practice waste separation and recycling (Owojori et al., 2022).

In addition, regarding to food-waste programs, schools can advise students to manage their eating habits during breaks to prevent excessive consumption that may lead to increased waste at lunchtime. Encouraging moderation can help align hunger levels with food intake (Chu

et al., 2023). Schools can promote the use of lunchboxes for uneaten food or encourage meal sharing among students (Chu et al., 2023)

Implementing 3Rs (Reduce, Reuse, and Recycle) is important as well at school in order to foster waste management programs (Cahyanti et al., 2019; Giurea et al., 2024; Pardal et al., 2020). Reduce can be implemented by encouraging the use of electronic communication and digital platforms to minimize paper waste. Reuse can be done by setting up designated areas for donating and collecting reusable items like textbooks, electronics, furniture, and clothing. Recycle can be done by establishing accessible and clearly marked recycling stations throughout the school, such as making recycled paper. The goal of the program is to avoid waste going to landfills by promoting a circular economy (Pardal et al., 2020). The school should place eco points for waste separation and composting, promote waste prevention practices, and encourage reusing materials in seminars and events.

Planning waste management programs can use technology and digital solutions as well to optimize innovation and research (Giurea et al., 2024). School can conduct research on innovative waste management technologies and initiatives that can be implemented, such adopting digital platforms and technologies to monitor waste generation, track recycling rates, and streamline communication between classes and the waste management team. This can help identify areas of improvement and measure the effectiveness of waste management practices. Therefore, to support effective waste management programs, it is suggested to improve waste management infrastructure (Budihardjo et al., 2021). This includes providing adequate facilities for waste separation, such as waste bins for organic and inorganic waste, and improving the schools' waste processing center.

3. Action-Oriented Approaches

Schools should provide practical experiences related to waste management, such as organizing recycling drives or composting projects, to reinforce theoretical knowledge and encourage active participation (Saseanu et al., 2019). This action-oriented approach can also involve overcoming barriers such as time constraints and curriculum limitations to promote active participation in sustainability initiatives (García-Fortes et al., 2024).

For instance, the initial activity can be done by implementing eco-audits in nearby environments (e.g., schools or homes) to help students recognize the amount of waste generated, its origins, and assess its management. Besides, providing hands-on experiences in managing waste, such as composting, recycling, and using biogas, can help students understand the environmental impacts of waste and its management (Cahyanti et al., 2019). This experiential learning approach ensures that concepts are internalized better. This hands-on approach encourages critical thinking about waste issues (García-Fortes et al., 2024).

The students can be given task that should be done at home. Activities such food preparation and storage can be implemented in given-task. Implementing better food preparation and storage practices can minimize waste (Filho et al., 2024). Teach students practical skills related to food preparation and planning, which can help reduce waste at the household level (Catalano et al., 2024). This includes lessons on meal planning, proper storage techniques, and understanding expiration dates.

Promote projects where students create products from waste materials. For example, students designed food products from waste, which not only showcases their creativity but also highlights the potential for recycling and reusing materials (Rahmawati et al., 2017). Initiate community gardening projects that utilize recycled materials, teaching participants how to grow food sustainably and reduce waste simultaneously (Hidayati et al., 2021). Establish competitions among classrooms or schools to encourage better waste management practices (Rada et al., 2016). Recognizing and rewarding the best-performing classes can motivate students to engage actively in recycling and waste reduction efforts.

Involve students in practical activities, such as observing local industries (e.g., tofu factories) to identify waste management issues (Rahmawati et al., 2017). This hands-on

experience fosters a deeper understanding of waste problems and solutions and can foster a sense of responsibility and encourage them to apply their knowledge in real-world settings (Catalano et al., 2024).

4. Awareness Campaigns

Conducting awareness and accountability programs focused on the importance of waste reduction and recycling can help educate the urban population about their environmental responsibilities (Saseanu et al., 2019). Conduct regular educational campaigns and workshops to raise awareness among the school community regarding the importance of waste management and sustainable practices. Involve students in waste management decision-making processes and provide opportunities for innovation and engagement (Giurea et al., 2024). Offering educational programs, workshops, and training sessions can help individuals understand the importance of waste management and their role in the process (Musicus et al., 2022; Pardal et al., 2020). Provide training and guidelines on proper waste management practices, such as reducing plastic waste, reusing materials, and responsibly disposing of hazardous waste.

School can conduct awareness campaigns to educate students and staff about the importance of waste separation and 3Rs programs (Rada et al., 2016). These campaigns can include workshops, seminars, and interactive activities that engage students and foster a culture of sustainability within the school. Encourage discussions around social norms related to food waste and sustainability. By fostering a supportive environment, students are more likely to adopt positive behaviors and influence their peers (Elnakib et al., 2024).

Promote the importance of separate waste collection systems within educational institutions (Catalano et al., 2024). Activity can enhance environmental sensitivity and responsible waste disposal. The other example to promote awareness among student is the recognition of the harmful effects of microplastics on health to influencing zero-waste behaviors (Choi et al., 2022). Education should focus on raising awareness about how microplastics, found in plastics and everyday products, can harm human health and the environment (Choi et al., 2022).

Other way to raise awareness among students is schools should create incentives to motivate students to actively participate in waste reduction initiatives. This could include competitions or recognition for classes that generate the least amount of waste (Chu et al., 2023).

In addition, leverage social media and online platforms to spread awareness about food waste and sustainable practices among students (Hidayati et al., 2021). Educating students about the importance of minimizing waste, alongside initiatives like meal-sharing and reducing portion sizes, can significantly decrease food waste (Musicus et al., 2022). Engaging content can help reach a wider audience and encourage participation (Catalano et al., 2024).

5. Community Engagement

Partnering with local authorities and organizations can enhance the effectiveness of educational programs by providing resources and support for waste management initiatives (Cahyanti et al., 2019; Catalano et al., 2024; de Jager, 2015; Filho et al., 2024; Saseanu et al., 2019). Such partnerships help develop comprehensive programs that align with sustainable development goals. This can include food recovery programs and community awareness campaigns. Collaborating with local waste management agencies, recycling facilities, and community organizations to ensure proper disposal and recycling of different waste streams. Collaboration can facilitate better resource sharing, support for recycling initiatives, and compliance with local regulations (Dayaday & Galleto, 2022). This can include establishing partnerships for waste collection and recycling services or participating in local waste management initiatives (Giurea et al., 2024).

For instance, school can donate excess food to non-profits or use it for animal feed, ensuring compliance with food safety regulations (Filho et al., 2024). School can also encourage students and staff to donate clothes, furniture, textbooks, and other items that can be reused by others. Engage students, faculty, and staff through partnerships with local waste management

agencies, environmental organizations, and sustainable businesses (Giurea et al., 2024). Collaborate on waste reduction initiatives, research projects, and awareness campaigns

As mentioned before, food preparation and storage can be an activity that students can prepare it at home. This can encourage students to share their knowledge about food waste with their families and communities. Providing informative materials that can be used at home can help reinforce the lessons learned at school and promote sustainable practices in the wider community (Rada et al., 2016). This can amplify the impact of the education received in schools (Elnakib et al., 2024). Schools can serve as community hubs for environmental education, where students can lead initiatives that promote waste reduction and recycling within their families and neighborhoods (Saseanu et al., 2019). This approach amplifies the impact of education beyond the classroom.

6. Teacher Training

Enhance teacher training programs to equip future teachers with the necessary knowledge and skills to address sustainability issues effectively (García-Fortes et al., 2024). Teachers should receive adequate training on waste management and environmental sustainability to effectively deliver the curriculum (de Jager, 2015). Experienced mentors can assist in providing practical training, ensuring that educators are well-equipped to guide students. This includes fostering confidence in their ability to engage students in sustainability discussions and actions.

Develop and implement educational projects focused on waste management and sustainability. Training programs for teachers and staff can enhance their ability to educate students about proper waste disposal and recycling practices. This ensures that waste management becomes an integral part of the school curriculum (Rada et al., 2016).

CONCLUSION

The implementation of comprehensive waste management strategies in schools is crucial for fostering environmental awareness among students. By integrating sustainability topics into the curriculum, educational institutions can equip students with the knowledge and skills necessary to understand and address waste-related challenges. Engaging students in practical activities, such as recycling drives and composting projects, reinforces theoretical concepts and encourages active participation. These strategies aim to create a comprehensive educational framework that not only informs students about waste management but also empowers them to take action in their communities. Additionally, community involvement enhances these efforts, as partnerships with local organizations can provide essential resources and support. Together, these approaches create a robust framework that empowers students to become responsible stewards of the environment, ultimately promoting a culture of sustainability within the school and beyond.

In conclusion, prioritizing education for sustainable development and actively involving students in waste management initiatives are essential steps for schools to take in addressing environmental challenges. By fostering a culture of sustainability through practical engagement and collaboration with the community, schools can significantly influence students' attitudes and behaviors regarding waste. The active involvement of students, teachers, and the community is crucial for the success of these initiatives. This holistic approach not only prepares students to face sustainability challenges in their personal and professional lives but also encourages them to make positive contributions to their communities. Ultimately, by instilling a sense of responsibility and stewardship, schools play a pivotal role in advancing a sustainable future.

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