



Innovative Green Education Model Through Eco-Clubs: Enhancing Wastepreneurship Competencies in Higher Education for Sustainable Waste Management



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Abstract: The learning process plays a crucial role in developing character values, including environmental care value. Given the critical importance of the environment to human existence, addressing the increasing environmental challenges today requires the integration of environmental education into core learning processes. Developing learning that promote environmental values is essential for effective implementation. This study aims to: (1) develop a Green Education model through Eco-Clubs for students at Universitas Negeri Malang (UM), (2) evaluate the effectiveness of the Green Education model through Eco-Clubs for students, and (3) assess the wastepreneurship skills of students' participation in the Green Education model through Eco-Clubs. The study employed a Research and Development (R&D) methodology utilizing the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model. The research subjects were students of UM enrolled in the Entrepreneurship course. Data analysis employed a mixed-method approach. Results indicate that the Green Education model implemented through Eco-Clubs significantly enhances students' wastepreneurship competencies. Achieving successful environmental projects requires high levels of cooperation, creativity, and a strong sense of environmental responsibility. These factors significantly influence students' ability to address environmental issues, particularly waste management, both on campus and within the community. Furthermore, the implementation of the Green Education model using Eco-Clubs has enhanced student engagement in environmental initiatives, yielding beneficial outcomes for both the campus and broader community stakeholders.

Keywords: Green education; Eco-Clubs; Wastepreneurship; Environmental activities; Sustainable waste management

1 Introduction

Environmental issues remain a significant challenge for many countries, including Indonesia. Research shows that the root cause of many environmental problems lies in human behavior and attitudes towards the environment [1, 2]. Environmental problems are caused by human indifference and reluctance to participate in conservation efforts [3, 4]. Studies indicates that humans function not merely as social entities but also as ecological beings with significant environmental dependencies [5, 6]. Human activities should adopt sustainable environmental practices, ensuring that present resource utilization does not compromise the welfare of future generations [7, 8]. The reciprocal relationship between humans and nature establishes a value system wherein human judgment in environmental management directly influences ecological sustainability [9]. In this context, wastepreneurship plays a vital role as a holistic

approach to addressing environmental issues, especially waste management problems [10]. Common views and ecological views on nature management can be explained in Table 1.

Table 1. Common views and ecological views on nature management

No.	Dominant Viewpoint	Ecological Viewpoint
1	Dominance over nature	Harmony with nature
2	Natural environment as resource for human use	Recognition of all species' inherent rights and equality
3	Material/economic growth prioritized for human population expansion	Material serves a greater purpose of self-realization
4	Reliance on abundant reserve resources	Acknowledgment of Earth's finite resource limitations
5	High technological advancement and solutions	Technology remains useful, knowledge is not dominant
6	Consumption-oriented practices	Recycle so that it has more use value

Environmental management strategies should incorporate principles such as integration, sustainability, participation, and institutionalization [11]. Environmental ethics can be categorized into nine fundamental principles, with the first being the principle of respect for nature, which emphasizes that humans must care for, protect, and preserve the environment and its biodiversity [12]. Moreover, humans should not inflict harm on natural systems without morally justifiable rationales.

The principle of moral responsibility towards nature highlights that the environment belongs to all, and therefore, a sense of duty to protect it must be ingrained in human consciousness. The principle of cosmic solidarity encourages humans to safeguard the environment to protect all life on Earth, as all living beings have equal value. The principle of love and care for nature is a moral principle directed towards others, without expecting anything in return.

The “no harm” principle establishes that humans must refrain from engaging in activities that cause detrimental impacts on natural environment. The principle of living simply and in harmony with nature stresses values, quality of life, and ways of living rather than material wealth and standards. The principle of justice requires humans to behave justly towards anything related to the natural world, including social systems that should be structured to positively impact environmental sustainability. The principle of democracy advocates for respecting differences, diversity, and pluralism. Lastly, the principle of moral integration emphasizes that those in positions of power, expertise, or responsibility in environmental matters should uphold high moral standards when managing the environment.

In the context of the 21st-century digital era, integrating life skills into education can catalyze transformative development of a “golden generation”. Education should not only prepare students for the workforce but also foster critical thinking and environmental character to prevent an environmental crisis [13]. Comprehensive understanding of environmental ethics is anticipated to foster eco-conscious behavioral patterns among students. Wastepreneurship represents a significant ethical framework that addresses waste management challenges through principles of environmental respect, care, and responsibility [14, 15]. The importance of wastepreneurship for students is to raise awareness of environmental crises, particularly in preparing for disaster resilience [16, 17].

This conceptual framework aligns with four classified forms of local wisdom related to forest resource management: 1) beliefs and taboos, which establish intrinsic connections between humans and nature, thereby necessitating environmental preservation; 2) ethics and regulatory systems, which manifest positive environmental stewardship through prohibitions, permissions, and sanctions for non-compliance; 3) indigenous techniques and technologies, which employ methodologies and implements designed to maintain ecological equilibrium; and 4) communal practices and traditions oriented toward forest conservation for collective benefits [18]. Previous research on wastepreneurship and local wisdom indicates that local traditions play an essential role in preserving the environment [19, 20]. These values, such as the Javanese local wisdom “*memayu hayuning bawana*”, provide frameworks for sustainable environmental management. This local wisdom has been embraced by communities in Java and Indonesia as a principle to manage the environment that prioritizes collective welfare [21, 22].

Currently, efforts are required to foster environmental consciousness in individuals, with education serving as a fundamental mechanism to achieve this goal [23, 24]. Ideally, the learning process for students should extend beyond knowledge transfer to include character development, particularly environmental care and appreciation of natural beauty [25]. Accordingly, research on developing Green Education models through Eco-Clubs in environmental geography courses is essential Green Education, which focuses on enhancing self-efficacy and applying ecopedagogical principles, is crucial for students to internalize positive environmental values while developing their environmental competence and awareness [26, 27]. Furthermore, the study of Environmental Ethics cannot be confined to limited face-to-face meetings; direct field-based learning is necessary to instill a deeper environmental awareness.

“*Memayu Hayuning Bawana*” represents an open interpretation of local wisdom that has become the foundation for managing the environment, guiding communities in Java and across Indonesia on how to improve environmental conditions for the well-being of people and nature. Environmental preservation actions guided by the “*Memayu Hayuning Bawana*” philosophy address various environmental threats while prioritizing ecological safety and well-being [28, 29]. Better environmental conditions lead to improved human welfare. Therefore, environmental education should increase awareness about proper natural resource management, environmental care, and national pride [30]. Thus interdisciplinary environmental education programs should combine theoretical knowledge with practical teaching skills, especially in Green Education, to develop environmental awareness [31].

Implementing a Green Education model through university Eco-Clubs is essential for fostering students’ environmental awareness. The research emphasizes the importance of establishing a campus culture where environmental stewardship is integrated into educational practices, a crucial factor in shaping students’ environmental care attitudes. This includes maintaining clean classroom environments, improving sanitation practices, minimizing plastic waste, promoting river conservation, organizing plastic waste collection events, and conducting tree planting activities during environmental observances such as Earth Day or World Environment Day. These sustainable practices contribute significantly to environmental conservation. The objectives of this study are to: (1) develop an effective Green Education model implemented through student Eco-Clubs; (2) evaluate the efficacy of the eco-club-based Green Education model; and (3) measure the development of students’ wastepreneurship skills (the ability to create value from waste materials) following their participation in the Green Education model via Eco-Clubs.

2 Method

2.1 Research Location

This study was conducted at Universitas Negeri Malang (UM), located at Jalan Semarang No. 5, Malang, Indonesia. The location was selected because it offers an optimal environment for implementing the Green Education model through Eco-Clubs, particularly focusing on student participation in waste management practices. The university offers access to academic and extracurricular activities that allow the implementation of the Research and Development (R&D) methodology with the Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model. The ADDIE framework was selected for its systematic and structured approach, which corresponds effectively with established principles of instructional design [32]. This methodological approach ensures thorough coverage of all research phases while enabling precise assessment at each implementation stage.

2.2 Research Design

This research employed a R&D methodology based on the ADDIE model. This framework was selected for its systematic and iterative nature, which is particularly appropriate for developing and evaluating educational interventions within the context of Green Education and wastepreneurship through Eco-Clubs. The methodological design incorporates a sequential approach to creating, implementing, and assessing the Green Education model:

- *Analysis*: Identifying the learning needs of students and challenges related to environmental education at the university. In addition, observations were also carried out with the aim of identifying problems in the learning process, environmental education and environmental practices among students. This phase includes understanding the context, the knowledge gaps in environmental practices, and the current level of student engagement in waste management.

- *Design*: Developing the Green Education model, including the creation of instructional materials and activities aligned with the goals of Wastepreneurship. In the design phase, the creation of instructional materials and activities involves first determining the design by creating a storyboard. This will help ensure the materials and instructional activities are structured. This phase also defines the framework for evaluating the effectiveness of the model.

- *Development*: Producing the necessary learning materials, such as project guidelines, instructional content, and assessment tools. This stage also involves developing waste management projects for Eco-Clubs.

- *Implementation*: Implementing the Green Education model through Eco-Clubs, where students are directly involved in waste management activities. This phase includes both the theoretical and practical application of waste management techniques. The theory session introduces key concepts in environmental management and wastepreneurship. The practical session involves hands-on activities such as waste collection, sorting, recycling, and product marketing.

- *Evaluation*: Assessing the effectiveness of the model by measuring the student outcomes related to wastepreneurship and environmental awareness. Evaluation includes both formative and summative assessments to ensure the success of the Green Education model. The formative evaluation phase is used to ensure appropriate strategies and materials are used in the learning process. Summative evaluation is conducted in the final phase with the aim of determining the overall impact of education in the context of Green Education and wastepreneurship through Eco-Clubs.

Each phase of the ADDIE model was followed systematically to ensure the model’s development and implementation were consistent, rigorous, and effective in achieving the desired learning outcomes. The stages of R&D of Green

Education and wastepreneurship through Eco-Clubs can be explained in Figure 1.

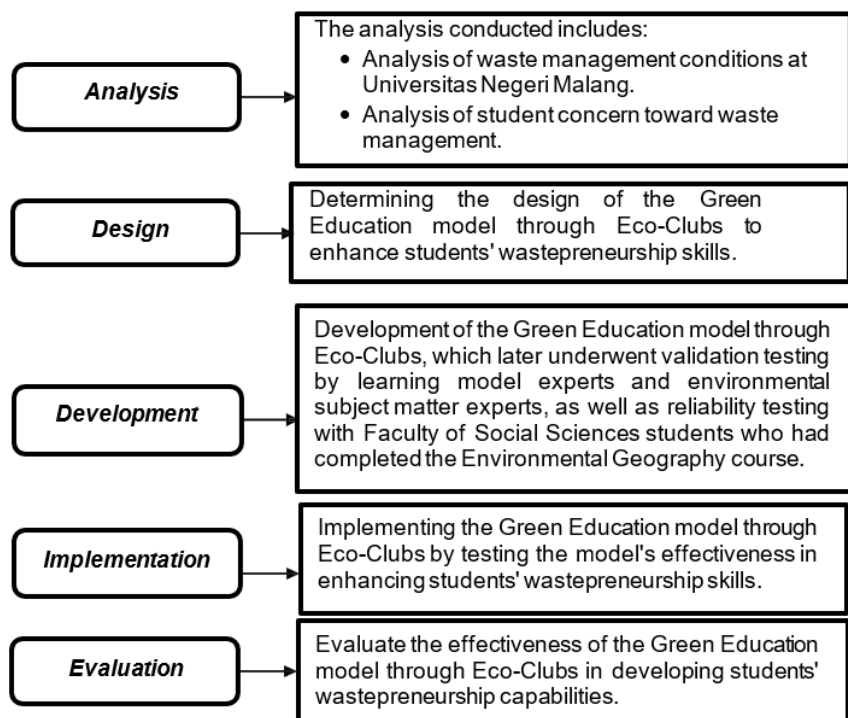


Figure 1. Stages of Research and Development (R&D)

2.3 Data Collection Techniques

The study employed both quantitative and qualitative data collection methods to provide a comprehensive assessment of the Green Education model's effectiveness in enhancing student engagement and developing wastepreneurship skills. Data collection was conducted at the State University of Malang with research subjects from various faculties such as the Faculty of Engineering, Faculty of Psychology, Faculty of Social Sciences, Faculty of Mathematics and Sciences, Faculty of Economics and Business, Faculty of Letters, Faculty of Vocational Studies, Faculty of Educations, Faculty of Medicine, Faculty of Sport Sciences. Purposive sampling was used as a technique in determining research subjects. The selection of research subjects was determined based on waste problems so that the implementation of the innovative green education model through Eco-Clubs was required.

Data collection took place weekly and included information gathered from 10 Faculties. Determination of data validity and reliability was carried out collaboratively by a research team consisting of a Professor with more than 35 years of environmental science expertise, one senior lecturer with 7 years of expertise in geography education, four senior lecturers with doctoral degrees with expertise in education, early childhood education, environmental education, and entrepreneurship, two graduates of master's degrees in geography education with expertise in waste management. Validity and reliability were determined based on the Intraclass Correlation Coefficient with a value of 0.8 [33].

Data were collected through observations, interviews, and documentation, ensuring a holistic approach to evaluating the model's impact.

Observations were conducted throughout the model implementation on a weekly basis to monitor student participation and engagement in Eco-Clubs, track changes over time, and assess students' involvement in waste management activities. Semi-structured interviews were conducted with students and Eco-Club coordinators to gain insights into their experiences with the Green Education model, including the challenges they encountered and their perceptions of the model's effectiveness. These interviews provided qualitative data on the impact of the model on student attitudes, as well as on the practical aspects of the Eco-Clubs' activities.

Additionally, comprehensive documentation of student projects was collected to assess the outcomes of the Eco-Clubs. This documentation included records of waste management activities, products developed from recycled materials, and contributions to campus sustainability initiatives. The data also encompassed the economic valuation of waste-derived products, which served as a metric to evaluate the entrepreneurial dimension of wastepreneurship.

Expert validation of the model was conducted to ensure the Green Education model aligned with the objectives of promoting wastepreneurship and environmental responsibility. The model's effectiveness was subsequently tested through a Waste Management Competition, where students presented projects involving waste management and

recycling. These projects were evaluated by a panel of judges based on creativity, environmental impact, and feasibility.

2.4 Data Analysis

Data analysis used quantitative and qualitative methods, known as mixed methods, to ensure a robust evaluation of the impact of the Green Education Model. The combination of quantitative and qualitative methods is known as a method that can produce valid and reliable data [34]. The mixed methods research design employed an Exploratory Sequential Design, implementing two phases of data collection [35]. The first phase involved qualitative data collection aimed at exploring findings or phenomena. The second phase involved quantitative data collection aimed at interpreting the data from the research findings. Quantitative data from observations and project documentation were analyzed using tabulation, percentages, and graphical representations to illustrate trends in student participation, activity typology, and economic valuation of products derived from recycled materials. This analytical approach facilitated an objective assessment of the Green Education model's effectiveness in fostering waste entrepreneurship skills and promoting student engagement in sustainability initiatives.

Qualitative data underwent interactive analysis following the methodology proposed by Miles and Huberman [36]. The analytical process comprised four distinct stages: 1) Data collection, involving the gathering of data from interviews, focus groups, and project documentation; 2) Data reduction, wherein irrelevant or excessive data were discarded and key themes identified; 3) Data display, whereby data were organized visually into matrices, diagrams, or thematic clusters to facilitate interpretation; and 4) Conclusion and Verification, wherein findings were drawn from the analysis and validated through triangulation with expert feedback and comparative analysis with existing literature. This mixed-methods approach generated both robust statistical evidence and nuanced qualitative insights into the effectiveness of the Green Education model in fostering waste entrepreneurship and environmental care attitudes.

3 Result and Discussion

This section presents the key findings of the study and examines their implications within the context of the research objectives. The purpose is to establish a foundation for a comprehensive analysis of how outcomes from the Green Education model implemented through Eco-Clubs contribute to student engagement, waste entrepreneurship development, and environmental sustainability enhancement.

The study aimed to evaluate the effectiveness of the Green Education model implemented through Eco-Clubs at UM in enhancing students' waste entrepreneurship skills and promoting environmentally responsible behavior. This model was designed to engage students in hands-on waste management projects, enabling them to apply theoretical knowledge to real-world environmental challenges.

The results presented herein provide insights into how the Eco-Clubs facilitated active learning, fostered creative problem-solving, and contributed to the development of entrepreneurial skills in students. The discussion explores the significance of these findings in relation to the broader objectives of environmental education, waste entrepreneurship, and sustainable community development.

The results and Discussion sections analyze data gathered from student participation, project outcomes, and the impact of the Eco-Clubs. The relationship between these results and theoretical frameworks—including active learning [37, 38], multiple intelligences [39], and entrepreneurship education [40]—is critically examined. Contextualizing the results within these theories highlights the innovative aspects of the Green Education model and its potential for scalability across diverse educational settings.

Finally, this section addresses the limitations of the study, proposes future research directions, and examines the broader implications of these findings for fostering sustainable behaviors and entrepreneurial initiatives among university students.

3.1 Green Education and Waste entrepreneurship

The implementation of the Green Education model through Eco-Clubs has demonstrated a significant relationship between student engagement in environmental projects and the development of waste entrepreneurship skills. Analysis of data collected from student participation metrics, waste management project outcomes, and Waste Management Competition results illuminates how this model contributes to promoting sustainable practices and entrepreneurial thinking among students.

A substantial proportion of students participated actively in the Eco-Clubs, mostly from the Faculty of Mathematics and Natural Sciences (38.8%), followed by the Faculty of Social Sciences (21.2%) and the Faculty of Engineering (12.9%) (Figure 2). This distribution demonstrates engagement from students across diverse academic disciplines, underscoring the interdisciplinary appeal of the Green Education model. Student projects focused on transforming waste materials into valuable products, evidencing their capacity to apply waste entrepreneurship principles creatively.

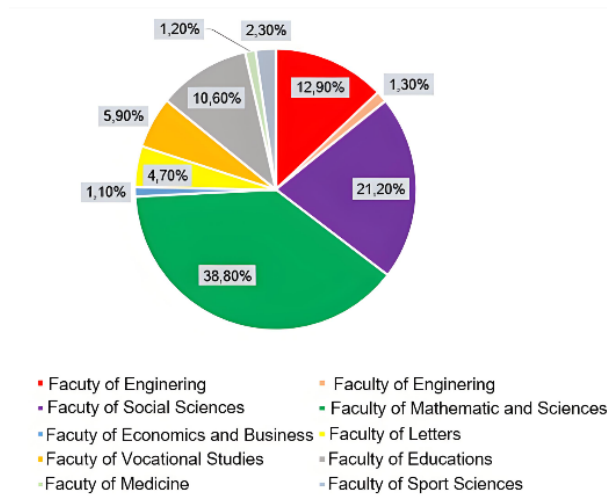


Figure 2. Percentage of participants by faculty

The Green Education model, implemented through the Eco-Clubs, provided students with the opportunity to engage in active learning, allowing them to take ownership of environmental issues and creatively solve problems related to waste management. This approach aligns with the theory of active learning [37, 38], which emphasizes that students learn best when they are actively involved in their own learning process, particularly in real-world, hands-on projects. Furthermore, previous research findings indicate that green education implemented in learning environments can enhance students' environmental knowledge and behaviors [41, 42].

The active participation in Eco-Clubs and the creation of waste-based products reflect the principles of entrepreneurship education, where students are encouraged to think creatively, identify opportunities, and develop sustainable solutions to environmental problems. The products created by students, although not all economically viable, demonstrate their capacity for innovation and resourcefulness, key characteristics of an entrepreneurial mindset. The distribution between low-value products (79%) and high-value products (21%) indicates that while there are significant opportunities for creativity and innovation, there is still room for improvement in making these projects economically viable (Figure 3). These findings suggest that while students demonstrate capacity for generating innovative solutions to environmental problems, the economic viability of certain projects remains a challenge. Nevertheless, the demonstrated ability to transform waste into functional products represents a significant developmental milestone in entrepreneurial skill acquisition. Moreover, it suggests that future iterations of the Green Education model could benefit from incorporating business models or market-driven approaches to enhance the economic potential of student projects, thus strengthening the link between environmental sustainability and entrepreneurship.

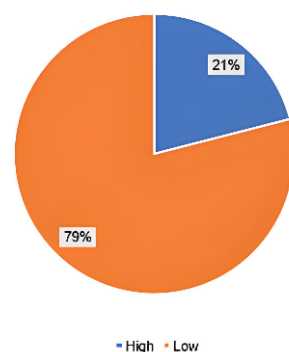


Figure 3. Value of waste management products by students

The projects developed by students primarily focused on raising awareness and encouraging positive behavioral changes within the community. The most common outputs were videos promoting environmental awareness (no product) (78%), followed by upcycled products made from waste materials (22%) (Figure 4). This variety of products illustrates the diverse ways in which students can address environmental challenges while fostering creativity and resourcefulness, as it the core aspects of wastepreneurship.

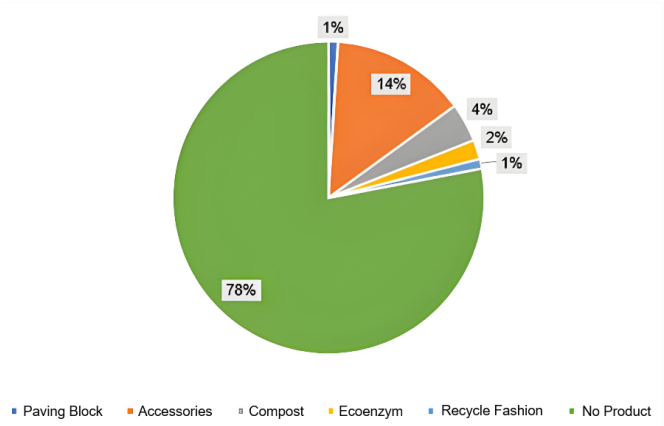


Figure 4. Types of waste management products made by students

Regarding waste origin, the majority of materials utilized in the projects were sourced from campus facilities (77%), with the remaining 23% obtained from external sources (Figure 5). This finding indicates that students exhibit heightened awareness of waste generated within their immediate environment and demonstrate motivation to address these challenges through localized initiatives.

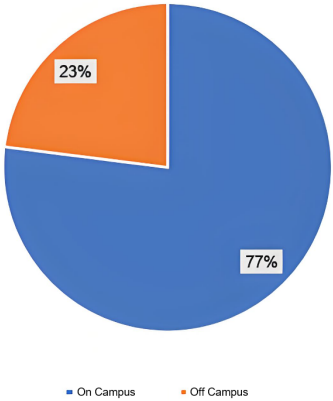


Figure 5. Origin of waste handled by students

Furthermore, the waste processed by students was predominantly solid waste (98%), with minimal engagement in liquid waste management (2%) (Figure 6). This distribution corresponds with contemporary waste management challenges faced by many institutions, where solid waste management typically receives greater attention and resources.

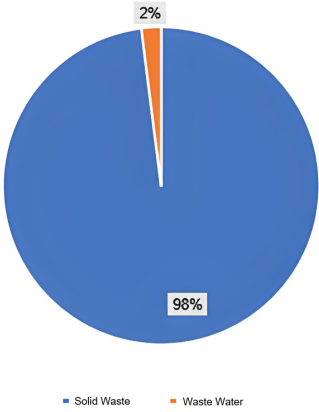


Figure 6. Types of waste handled by students

The multiple intelligences theory [39] offers further insight into how the Green Education model can foster diverse forms of creativity and intelligence. For example, students with strong logical-mathematical intelligence may excel in analyzing waste management processes, while those with interpersonal intelligence may focus on creating projects that engage and motivate the community. The diversity of products generated, from educational videos to upcycled products, highlights how students from different backgrounds and with varying skill sets contribute to a collective entrepreneurial effort to address environmental challenges.

The fact that most of the waste used in the projects came from the campus indicates a high level of environmental awareness and responsibility among students, who demonstrate increasing cognizance of waste generated within their immediate environment and motivation to take action. This exemplifies the environmental literacy developed through the Green Education model, which equips students with the knowledge and skills needed to assess and manage their environmental impact effectively [43]. The predominant focus on solid waste corresponds with the substantial challenges that many campuses and communities face in managing waste disposal, particularly regarding plastic and other non-biodegradable materials that require innovative approaches for sustainable management.

Furthermore, the projects' focus on raising awareness and encouraging behavior change highlights the social responsibility aspect of wastepreneurship. The students are not only concerned with solving waste problems but are also creating a ripple effect within their communities by engaging the public in environmental practices. This approach aligns with the concept of community-based learning, wherein students apply their knowledge to create positive change in their communities [44]. The video projects, in particular, serve as powerful tools for disseminating environmental awareness and motivating broader adoption of sustainable practices.

While the study has demonstrated positive outcomes, it is important to acknowledge some limitations. The low economic value of the majority of the products indicates that despite students' engagement in innovative projects, there remain challenges in ensuring long-term sustainability of these initiatives. Consequently, future research could explore methods to integrate business strategies into the Green Education model to further enhance the entrepreneurial potential of students, thereby ensuring that their projects not only address environmental issues but also contribute substantively to sustainable economic development.

3.2 Active Learning as a Driver of Student Engagement

The Green Education model, implemented through Eco-Clubs, served as a platform for active learning, which, as the data indicate, significantly enhanced student engagement and participation in environmental projects. Throughout the study, students participated in waste management initiatives, demonstrating their ability to explore, create, and implement environmental solutions. This hands-on involvement manifested in the variety of waste management projects developed by the students, including upcycling initiatives, recycling processes, and community engagement through educational campaigns.

The active participation in Eco-Clubs was facilitated by a project-based learning approach that allowed students to engage with environmental problems directly. The Waste Management Competition, held during the National Waste Care Day (*Hari Peduli Sampah Nasional*), was one such example of how active learning encouraged students to apply their creativity in practical contexts. Students collaborated in teams to manage waste, produce useful products, and present their work in a competitive setting. This competition not only fostered teamwork and creative thinking but also enhanced students' sense of ownership and responsibility for addressing real-world environmental challenges.

The projects, which were mainly student-driven projects, demonstrated the effectiveness of active learning. As students developed their waste management initiatives, they were not just passive recipients of information but active participants in the learning process, directly engaging with their surroundings. This approach encouraged deeper learning and critical thinking, as evidenced by the diversity of projects (e.g., videos, recycling products, and community campaigns) produced by the students. Moreover, students were encouraged to explore innovative solutions, which further highlighted the role of active learning in fostering creativity and problem-solving skills in real-world contexts [45].

The findings from this study emphasize the crucial role of active learning in driving student engagement, particularly in environmental education. As demonstrated by the Eco-Clubs and their associated projects, this learning approach extends beyond knowledge acquisition to the application of that knowledge in practical, meaningful ways that address real-world issues. Active learning, as defined by scholars such as Jagantara et al. [37] and Kokotsaki et al. [38], encourages students to engage with material through hands-on, participatory methods centered around problem-solving [37, 38]. Through direct involvement in waste management projects, students effectively bridged the gap between theory and practice, deepening their understanding of the environmental challenges they were addressing.

The Green Education model effectively utilized project-based learning, a key component of active learning, where students took the lead in managing environmental issues. This aligns with findings from previous research indicating that project-based learning can enhance students' knowledge of environmental issues and environmental awareness [46]. This approach provided students with autonomy in their learning process, enabling them to design, implement, and evaluate their own projects. The direct involvement in real-world waste management initiatives

encouraged students to think critically, work collaboratively, and develop innovative solutions. These experiences align with the theoretical framework of constructivist learning, which posits that learning is most effective when students actively construct knowledge through experience and reflection [47, 48]. The results demonstrated that when students were empowered to take ownership of their learning process, they exhibited greater engagement and motivation to create meaningful solutions.

Additionally, the findings reveal that the active learning environment fostered by the Eco-Clubs significantly encouraged collaborative learning. Students worked in teams to tackle environmental problems, which promoted both social learning and the development of interpersonal intelligence [39]. Collaboration within these teams facilitated knowledge sharing, creative ideation, and peer learning, further enhancing student engagement. This pedagogical approach proves particularly effective for cultivating community-oriented behavior and social responsibility—values that constitute the foundation of wastepreneurship as a conceptual framework.

Moreover, the diverse projects generated by students, such as educational videos and upcycled products, demonstrate how active learning can stimulate creativity and innovation. These outcomes reflect the application of multiple intelligences theory [39], where students use their varied strengths—whether logical-mathematical, linguistic, or interpersonal—to engage with and solve environmental issues. For instance, students with stronger interpersonal intelligence may have excelled in creating community outreach campaigns, while those with logical-mathematical intelligence might have focused on analyzing waste management data or developing systems for recycling. This diversity of cognitive strengths allowed for a comprehensive approach to environmental problem-solving.

The importance of student autonomy in the Eco-Club activities cannot be overstated. As students were given the freedom to explore environmental issues on their own terms, they demonstrated greater initiative and a deeper commitment to finding sustainable solutions. This aligns with the principles of constructivist pedagogy, which emphasizes that students learn best when they are actively involved in the construction of their knowledge, rather than passively receiving information [49, 50]. Learning that involves students in direct interaction with the environment has been proven to facilitate easier comprehension of material [46, 51]. The autonomy afforded by Eco-Clubs allowed students to explore waste management issues from multiple angles, encouraging them to approach environmental challenges with a creative, entrepreneurial mindset—a key aspect of wastepreneurship.

Furthermore, the Waste Management Competition served as a motivating factor, compelling students to apply their knowledge in a competitive and public setting. The sense of competition, coupled with the recognition of their efforts, likely contributed to heightened engagement and a sense of achievement. This dynamic is consistent with self-determination theory [52], which suggests that students are more engaged when they feel competent, autonomous, and connected to others in their learning environment. The competition element provided a tangible goal for students to work toward, fostering a sense of accomplishment and validating the significance of their contributions in real-world contexts. The winners of the Waste Management Competition can be explained in Figure 7.



Figure 7. (a) First, second, third place winners and honorable mentions 1, 2, 3, and audience favorite; (b) first place winner project converting plastic waste into paving blocks

3.3 The Role of Multiple Intelligences in Environmental Literacy

The application of the Green Education model through Eco-Clubs demonstrated that students engaged with environmental issues using a variety of intellectual strengths, showcasing the relevance of multiple intelligences in fostering environmental literacy. Throughout the implementation process, as students participated in waste management projects and created innovative solutions to environmental problems, it became evident that their success was not solely based on academic knowledge, but on how they applied their diverse cognitive abilities.

For instance, many students from the Faculty of Mathematics and Natural Sciences (38.8%) excelled in the analytical aspects of waste management, utilizing their logical-mathematical intelligence to develop strategies for sorting, categorizing, and measuring waste (Figure 2). Others, particularly from the Faculty of Social Sciences

(21.2%), applied their interpersonal intelligence to engage with the community, creating campaigns or organizing activities to raise awareness about waste reduction and recycling. This exemplifies the impact of interpersonal intelligence, where students with strong social skills were able to effectively communicate and collaborate with others to influence positive environmental behaviors.

Multiple intelligences align with Howard Gardner's theory, which states that everyone possesses different types of intelligence, each with its own learning and problem-solving style [39]. Previous research suggests that Gardner categorized seven primary forms of intelligence: linguistic-verbal, logical-mathematical, musical, spatial, bodily-kinesthetic, interpersonal, and intrapersonal [53]. Further work by Gardner further adds spiritual and existential intelligences to the list [54]. In the context of environmental education, the intelligences based on Howard Gardner's theory play a crucial role in how students address environmental issues [55]. This aligns with previous research that multiple intelligences can address complex challenges such as waste management [56].

Intelligence based on Howard Gardner's theory relevant to the research results is interpersonal intelligence, which can be proven in students of the Faculty of Social Sciences, demonstrating collaboration and involvement with the community in waste reduction and recycling. Interpersonal intelligence has a positive impact, such as students possessing social skills in collaboration, which influences positive behavior towards the environment [57]. Students with high interpersonal intelligence are able to build relationships, work in teams, and effectively communicate with others to promote environmental awareness and change [58]. This ability to engage people in collaborative environmental actions serves as a vital component of wastepreneurship—an approach where collective efforts generate sustainable waste management solutions.

Linguistic intelligence is included in Howard Gardner's theory, which has an important role in the creation of communication materials, especially educational videos developed as part of student projects [59]. These materials not only raised awareness but also demonstrated how language skills effectively influence and persuade others, thereby amplifying the impact of the Eco-Clubs' environmental initiatives. This is in line with Gardner's statement that linguistic intelligence is crucial for influencing social action and a key component of entrepreneurship, as strategic delivery of ideas is crucial for gaining support for sustainable business models and social initiatives [60].

Moreover, the linguistic intelligence of students manifested in the production of educational materials, particularly in videos created to raise awareness about waste management. These projects necessitated the application of advanced language and communication skills to convey complex environmental messages in an engaging and accessible manner. The development of these media resources demonstrated that students with strong verbal-linguistic intelligence could effectively leverage storytelling techniques and persuasive communication strategies to mobilize their peers and broader community in support of environmental initiatives.

Logical-mathematical intelligence, as demonstrated by students from the Faculty of Mathematics and Natural Sciences, proved essential for understanding and analyzing the technical aspects of waste management, including the quantification of waste materials, categorization methodologies, and optimization of recycling processes. Students with strong logical-mathematical intelligence were able to approach waste management as a problem to be solved through systems thinking and data analysis. This cognitive strength enabled them to engage with problems analytically, thereby enhancing their contributions to wastepreneurship through practical, measurable outcomes.

Students with kinesthetic intelligence played a crucial role in the practical aspects of waste management. These students excelled specifically in hands-on tasks such as sorting and recycling waste materials. They showed effective problem-solving skills by using their physical capabilities to handle waste materials directly and convert them into useful products, such as upcycled items. This practical approach corresponds with Gardner's theory of kinesthetic intelligence, which describes the ability to use one's hands and body effectively to solve problems and create products [39, 61].

Furthermore, kinesthetic intelligence proved essential for the practical aspects of waste management. Students who excelled in this domain engaged effectively in the physical processes of sorting, recycling, and upcycling waste materials into usable products. These participants not only applied their physical capabilities to these tasks but also demonstrated that active engagement is central to developing environmental literacy. Through direct interaction with materials, students acquired knowledge experientially, reinforcing the significance of hands-on learning approaches in environmental education [62].

This diversity of intelligence among students emphasizes the need for a multifaceted approach to environmental education, where all forms of intelligence are valued and utilized. The Green Education model through Eco-Clubs effectively taps into these various cognitive strengths, encouraging students to use their diverse abilities to solve environmental problems in innovative ways. By fostering an inclusive learning environment that accommodates different learning styles and strengths, the model encourages collaboration, innovation, and creative problem-solving all essential components of successful wastepreneurship.

Moreover, this approach aligns with constructivist learning theory, which posits that learning is most effective when students actively engage in creating their own knowledge through real-world experiences [48]. In the context of Eco-Clubs, students were explicitly encouraged to leverage their individual intelligences to contribute to collaborative

projects. This pedagogical strategy reinforces the understanding that environmental literacy does not represent a one-size-fits-all concept but rather constitutes a multifaceted competency that can be cultivated through diverse, experiential learning opportunities [62, 63].

The integration of multiple intelligences into the Green Education model effectively highlights the significance of inclusive educational approaches in addressing complex environmental challenges. By systematically recognizing and cultivating the diverse cognitive strengths of students, educators can develop more engaging and impactful environmental education programs that foster sustainable thinking and entrepreneurial innovation. This comprehensive approach not only promotes environmental literacy but also equips students with the requisite skills to become proactive environmental leaders and agents of sustainable change in their communities and beyond.

In addition to multiple intelligences, the research findings have implications for environmental ethics. Student involvement in Eco-Clubs reflects a caring attitude toward the environment, demonstrated through the management of waste as a resource. This aligns with wastepreneurship projects, which can embody the principles of environmental ethics, particularly responsibility, sustainability, and stewardship [64, 65]. Interpersonal and linguistic intelligences, when linked to environmental ethics theory, facilitate students' moral actions in collaborating with others to engage in environmentally friendly behavior. Meanwhile, logical-mathematical and kinesthetic intelligences are demonstrated by students' concrete actions in designing and transforming unused waste into valuable products.

This research expands the theoretical understanding of multiple intelligences, which serve as pathways for implementing environmental ethics in practice. Therefore, environmental literacy is not a single competency, but rather a multi-intelligence construct enriched by an ethical commitment to sustainability. The integration of Gardner's theory with environmental ethics provides a strong theoretical framework for environmental education. This evidence demonstrates that multiple intelligences can foster an ethical orientation necessary for the environment and sustainable development.

3.4 Impact of Eco-Clubs on Campus and Local Community

The Eco-Clubs, implemented as part of the Green Education model, have had a significant impact on both the campus environment and the surrounding local community. The student-led waste management projects, which were central to the Eco-Clubs' activities, not only contributed to a cleaner campus but also fostered greater environmental awareness among the student body and local residents.

The projects created by Eco-Club members were often community-focused, aiming to raise awareness about waste reduction, recycling, and sustainable practices. One of the most notable outcomes was the Waste Management Competition, where students competed by presenting innovative waste management solutions. Projects like the upcycled products, such as bags made from canteen waste, were particularly well-received. These projects not only showcased students' creativity and entrepreneurial spirit but also had a direct, tangible impact on the campus and surrounding areas. For example, the bag-making project was an example of how waste could be repurposed into useful, marketable products, while simultaneously promoting sustainability (Figure 8).

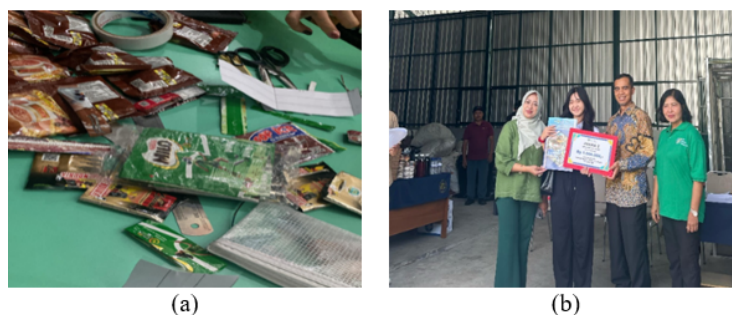


Figure 8. (a) Waste products transformed into fashionable bags; (b) second place winning team creating fashionable bags from plastic waste

Additionally, the majority of waste managed by students came from the campus itself, with 77% of the waste being sourced from campus areas (Figure 5). This demonstrates the students' growing awareness of the waste produced within their immediate environment and their initiative to manage it. The students' involvement in waste management projects extended beyond their academic setting, as many projects were designed to engage local communities. For instance, educational videos created by the students were shared with the local community, helping to spread awareness about waste reduction and environmental conservation beyond the campus (Figure 4).

The results underscore the significant social and environmental impact of Eco-Clubs, both on the campus and in the local community. The waste management projects not only addressed the practical challenge of waste disposal but also played a key role in promoting environmental literacy and social responsibility among students. These

outcomes align with community-based learning theories, which suggest that when students are engaged in solving real-world problems within their local environment, they contribute to the society well-being while deepening their understanding of complex issues [44].

The direct involvement of students in managing campus waste, as reflected by the majority of waste sourced from the campus, demonstrates how local action can create systemic change. This focus on the campus as a learning lab highlights the importance of creating sustainable environments within educational institutions. By managing locally-generated waste, students directly contributed to improving their physical environment, making their learning experience both meaningful and practical. This practice resonates with sustainability education theories that emphasize the need for students to engage with and actively shape their immediate surroundings [66].

Moreover, the Eco-Clubs' efforts in reaching out to the local community through awareness campaigns, including educational videos and community-driven waste management projects, demonstrate the broader impact of the initiative. These actions reflect the principle of community-based learning, where students address problems within their immediate environment while extending their knowledge and solutions to surrounding communities [44]. The social responsibility aspect of wastepreneurship is evident in the students' engagement with the broader community to promote sustainable practices. By creating and sharing educational materials, students contributed to a culture of sustainability, encouraging positive behavior change among local residents.

The success of the Eco-Clubs also underscores the role of student leadership in driving community-based sustainability initiatives. The students' ability to create upcycled products and raise awareness through community outreach activities showcases their leadership in both environmental and social spheres. This ties into entrepreneurship education theories, which highlight the importance of leadership and innovation in fostering a culture of entrepreneurial action for social good [67]. Through their involvement in Eco-Clubs, students not only learned how to manage waste but also gained valuable entrepreneurial skills in creating marketable products from waste, a key aspect of wastepreneurship.

The effectiveness of Eco-Clubs in addressing both environmental and social issues aligns with multiple intelligences theory, highlighting the diverse skills and talents that students bring to environmental projects [39]. Students demonstrated how their unique cognitive strengths contributed to solving real-world environmental challenges through various activities: creating educational videos (linguistic intelligence) [68], developing upcycled products (kinesthetic intelligence) [69], and engaging with the community (interpersonal intelligence) [70]. This multidimensional approach to waste management not only enhanced students' environmental literacy but also empowered them to take action in both their immediate environment and the broader community.

3.5 Limitations and Future Suggestions

While the study provides valuable insights into the effectiveness of the Green Education model through Eco-Clubs in fostering wastepreneurship and environmental literacy, several limitations should be considered when interpreting the findings and planning future research.

First, sample size and diversity may limit the generalizability of the results. The study was conducted at a single university, and while student participation across different faculties provided some diversity, the findings may not be fully applicable to other universities or regions with different environmental or cultural contexts. Future research could benefit from expanding the sample to include multiple universities or broader demographics to assess whether the outcomes observed in this study can be replicated or modified in different settings.

Second, while quantitative data provided insights into student participation levels and product economic value, the subjective nature of certain assessments, such as project creativity, presents a potential limitation. The assessment of students' products, although validated through expert judges, could benefit from a more objective framework to evaluate sustainability and economic feasibility. Future studies could incorporate more rigorous metrics or standardized assessment tools to evaluate project impacts, offering a clearer picture of the entrepreneurial potential of Eco-Club initiatives.

Moreover, limitation relates to the study duration. Data were collected over a relatively short period, with the majority of assessment occurring during the Waste Management Competition. While this provided a snapshot of student engagement and creativity, it did not allow for long-term tracking of Eco-Club initiative outcomes. A longitudinal approach, tracking the impact of student projects over several semesters or years, would provide a more comprehensive understanding of the Green Education model's long-term effects on students' attitudes, behaviors, and entrepreneurial outcomes.

Limitations in addressing methodological challenges, such as bias in data collection, can arise during measurement or analysis. To mitigate this, triangulation can be applied by verifying qualitative data with observational and documentary data. Furthermore, if there are other limitations associated with methodological challenges, such as observational bias, minimize bias in observational results by conducting evaluations and follow-up to verify the results.

Additionally, the study did not fully capture the broader university support or challenges faced by students during

project implementation. For example, while students created innovative waste management products, external factors such as institutional policies, funding, and resource availability were not deeply explored. Understanding these contextual factors is crucial for providing a more comprehensive evaluation of the model's feasibility and scalability. Future research could explore the role of university support in facilitating or hindering the success of student-led environmental initiatives.

Despite these limitations, the findings open several avenues for future research. First, expanding the study scope to include multiple universities or a larger and more diverse student population could provide more robust data on the effectiveness of the Green Education model across different contexts. Comparing the impact of Eco-Clubs in various cultural and regional settings would shed light on how the model can be adapted to address local environmental challenges while fostering entrepreneurial and sustainable behavior.

Another promising direction for future research is to refine and standardize assessment tools for evaluating student project outcomes. The current study relied on expert judgment to assess the creativity and economic value of waste management products, but future studies could develop objective criteria or indicators to assess economic sustainability, market viability, and environmental impact. This approach would provide a more comprehensive measure of wastepreneurship initiative success and allow for more consistent comparisons across studies.

A systematic longitudinal investigation examining the sustained impact of Eco-Clubs on students' environmental behaviors and entrepreneurial outcomes is essential for comprehensive evaluation. This methodological approach enables researchers to empirically assess whether competencies and knowledge acquired through Eco-Club participation translate into enduring behavioral changes and entrepreneurial initiatives. Moreover, examining how program alumni address environmental challenges and pursue entrepreneurship in their post-graduate careers would contribute significantly to understanding the extended benefits of the Green Education model.

Furthermore, institutional support and policy integration are key factors that could enhance the success and scalability of the Green Education model. Future research should investigate how university policies, funding structures, and collaborations with external stakeholders (such as local governments or businesses) can facilitate or constrain student-led environmental initiatives. This would provide a more holistic view of the challenges and opportunities for implementing sustainable and entrepreneurial education at the university level.

Lastly, future research should examine the integration of digital technologies to enhance the Green Education model. Implementation of digital tools, learning management systems, and social media platforms expands the reach of Eco-Clubs, enabling remote participation and broader community engagement. This approach facilitates comprehensive documentation and dissemination of student projects, fostering global collaboration on environmental sustainability challenges. Investigating the complementary relationship between online learning platforms and traditional Eco-Club activities will establish a more inclusive and scalable framework for environmental education.

4 Conclusions

This study demonstrates that the Green Education model implemented through Eco-Clubs effectively enhances wastepreneurship skills among students. Through participation in hands-on waste management projects, students developed strong teamwork, creativity, and environmental awareness—essential qualities for addressing environmental challenges on campus and in surrounding communities. The success of these projects, particularly the creation of upcycled products and awareness campaigns, highlights the effectiveness of combining entrepreneurship with sustainability education. The key contribution of this research is its integration of active learning with wastepreneurship, enabling students to apply theoretical knowledge to real environmental problems. This educational approach fostered both environmental stewardship and entrepreneurial thinking, allowing students to develop marketable solutions from waste materials.

From a theoretical perspective, the findings of this study can contribute to environmental education by providing empirical evidence that integrating entrepreneurship elements into sustainability curricula can strengthen environmental literacy and economic empowerment. This is proven by research results that environmental learning is most impactful when combined with socio-economic dimensions such as waste entrepreneurship. In the area of waste entrepreneurship, these findings offer theoretical validation for the integration of green entrepreneurship education within higher education institutions. The results suggest that combining entrepreneurship pedagogy with environmental problem-solving can serve as a replicable framework for fostering sustainable business innovation.

Based on these findings, several directions for future research are recommended. Expanding the model to other universities and communities would test its effectiveness in different settings. Incorporating business models into student projects would enhance their economic feasibility and market potential. Conducting longitudinal studies would assess the long-term impact on students' behaviors and career choices. Additionally, integrating institutional support and external partnerships would improve the sustainability and scalability of these initiatives. In conclusion, the Green Education model through Eco-Clubs offers a promising approach to fostering environmental literacy and entrepreneurship, empowering students to become effective agents of change in addressing environmental challenges in their communities and beyond.

Author Contributions

Conceptualization, S., A.K.P., S.Z., and E.Y.; methodology, S., A.K.P., S.Z., E.Y., and N.A.W.; software, N.A.W., M.A., N.S., and U.H.A.K.; validation, S., A.K.P., S.Z., E.Y., and N.A.W.; formal analysis, S., A.K.P., S.Z., and E.Y.; investigation, S., A.K.P., S.Z., E.Y., and N.A.W.; resources, S., A.K.P., S.Z., and E.Y.; data curation, N.A.W., M.A., N.S., and U.H.A.K.; writing—original draft preparation, S., A.K.P., S.Z., E.Y., and N.A.W.; writing—review and editing, N.A.W., M.A., N.S., and U.H.A.K.; visualization, N.A.W., M.A., N.S., and U.H.A.K.; supervision, S.; project administration, S., A.K.P., S.Z., E.Y., and N.A.W.; funding acquisition, S. All authors have read and agreed to the published version of the manuscript.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

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Conflicts of Interest

The authors declare that there is no conflict of interest.

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