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Eco-Entrepreneurship Incubation for High Schoolers: Utilizing AI-Driven Vision Recognition in Wetland Conservation

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Abstract:
This community service program aims to improve Artificial Intelligence (AI) literacy and strengthen entrepreneurial awareness among students of SMAN 4 Banjarmasin through a digital-based waste sorting learning model in wetland ecosystems. The method applied in this activity is Participatory Technology Development (PTD), which integrates socialization sessions, AI literacy workshops, and hands-on implementation using a web-based application system powered by Gemini AI Vision Recognition. This system is designed to identify wetland waste characteristics that are typically wet, mixed, and contaminated with sediment, making conventional sorting methods less effective. The results of the program show a significant improvement in students' cognitive understanding, indicated by an increase in the average score from 5.67 in the pre-test to 7.76 in the post-test. In addition, 93.1% of participants reported that they had never interacted with AI technology before, while 91.0% expressed high satisfaction with the learning experience. The implication of this activity is the development of an innovative circular economy-based environmental education model that integrates AI technology into waste management learning. This model is expected to be scalable and adaptable for other schools in wetland regions, enabling the transformation of environmental challenges into opportunities for digital innovation and student entrepreneurship development.

INTRODUCTION

Waste management in wetland ecosystems has become a critical global and local issue due to increasing urbanization and environmental degradation. Banjarmasin, as a wetland-based city, faces unique ecological constraints that directly influence waste handling systems and environmental sustainability. The importance of this issue lies in its direct impact on public health, ecosystem balance, and urban resilience. The main point is that ineffective waste management in wetland regions leads to cascading environmental problems. The reason is that natural drainage systems are highly sensitive to pollution loads and physical waste accumulation. Evidence shows that wetland areas are increasingly functioning as informal waste disposal channels, reducing ecological capacity and increasing environmental risk (Eresanya et al., 2025; Mukhopadhyay, 2022). This situation highlights the urgency of integrating modern technological approaches into environmental management. Therefore, this issue is important for society because sustainable solutions are needed to transform waste management systems into adaptive, intelligent, and community-based ecological practices.

The main problem in Banjarmasin is that the natural drainage system, particularly rivers, has shifted its ecological function to an informal waste-disposal site. This transformation has created serious environmental consequences, including water pollution, ecosystem degradation, and increased flood risk. The waste accumulation in wetland rivers has reached a critical level, significantly altering hydrological patterns and accelerating sedimentation beyond natural processes (Nile et al., 2025; Wohl et al., 2021). In addition, the widespread disposal of non-biodegradable waste such as plastics and styrofoam has intensified environmental pressure (Orhorhoro, 2025; Sharma et al., 2025). Public awareness remains low, especially regarding the long-term environmental impact of plastic waste (Gabriel et al., 2024; Mohanaprasadh et al., 2022). Sociocultural habits of riverside communities also contribute to this issue, as water bodies are perceived as natural waste-disposal channels. These conditions demonstrate that the core problem is not only technical but also behavioural and systemic.

Field observations indicate that waste management practices in Banjarmasin remain reactive and manual, with interventions typically occurring only after environmental disasters such as flooding. This condition reflects a lack of proactive and technology-driven environmental governance (Adomako et al., 2025; Cao et al., 2025; Tian & Wang, 2024). Flooding events are increasingly frequent due to blocked drainage channels caused by unmanaged waste accumulation. At the same time, although the younger generation demonstrates strong familiarity with digital technology, this capability has not been effectively translated into action to address environmental problems (Iqbal & Ahmad, 2021; Marco-Lajara et al., 2022; Sahoo et al., 2023). A significant awareness-action gap exists, where digital literacy remains consumptive rather than productive. Research also shows that without contextual technological integration, digital skills fail to produce real ecological impact (Husamah et al., 2025; Lo, 2024; Shakina et al., 2021). This gap becomes more critical in wetland environments, where physical conditions such as high moisture and sediment contamination require adaptive technological solutions. Therefore, this topic is highly relevant because it connects environmental urgency with opportunities for digital transformation in education.

Previous studies on environmental education and AI literacy highlight the importance of integrating technology into sustainability learning frameworks. Environmental education has been shown to improve students' conceptual understanding of waste management, particularly through structured learning approaches. For example, AI-based classification systems have demonstrated strong potential to improve waste identification efficiency and decision-making in environmental systems (Boffardi et al., 2021; Esposito et al., 2025; Gutierrez-Lopez et al., 2023). Other studies indicate that youth can achieve high levels of cognitive understanding in waste classification when exposed to structured educational interventions, with proficiency rates exceeding 80 per cent in controlled learning environments (Nag et al., 2024; Shafiee Rad, 2025). However, these improvements are often limited to theoretical understanding rather than practical implementation, indicating that environmental literacy does not always translate into real behavioral change. Therefore, while literature supports AI integration, it also highlights the need for applied, practice-based models that link knowledge with real environmental action.

Further literature emphasizes that AI-based environmental systems have strong potential to improve waste management efficiency and support sustainable urban development. AI applications in landfill management show promising performance in supporting environmental policy and achieving sustainability goals (Lair et al., 2024; Lakhouit, 2024). However, most existing systems rely on generalized datasets and standard environmental conditions that do not reflect the complexity of wetland ecosystems. Wetland waste is characterized by high moisture content, organic contamination, and sediment mixture, which reduces the accuracy of conventional detection systems. This reveals a critical research gap in the adaptation of AI technology to localized ecological conditions. In addition, most educational interventions fail to integrate entrepreneurial frameworks that transform environmental learning into economic opportunities. Therefore, there is a need for a more contextual, adaptive, and applied AI-based learning model that bridges environmental literacy, technological capability, and circular economy development in wetland-based communities.

Based on the identified conditions, the main problem in this community service program is the low level of AI literacy among students in applying digital technology for environmental problem-solving. Although students demonstrate strong familiarity with digital tools, their skills are not directed toward ecological solutions relevant to wetland challenges. In addition, waste management practices in schools remain conventional, lacking integration with modern technological systems and entrepreneurial frameworks. Another issue is the absence of adaptive learning tools that can translate environmental knowledge into practical action, particularly in waste classification and management. These limitations create a gap between technological potential and environmental application. Therefore, the specific problem addressed in this program is how to enhance AI literacy and environmental awareness among students through an applied digital waste management system suitable for wetland conditions and capable of supporting sustainable behavioural change and entrepreneurial development.

This community service program aims to improve students' Artificial Intelligence literacy and environmental awareness by implementing an applied digital waste-sorting system based on Gemini AI Vision Recognition. The program also seeks to foster entrepreneurial thinking by integrating circular-economy principles into environmental learning. The scope of the activity includes socialization, AI literacy training, and implementation of a web-based application designed to identify and classify wetland waste characteristics. This initiative is aligned with broader educational and sustainability goals by promoting active student engagement in solving real environmental problems. In addition, the program supports the development of practical digital skills that can be applied beyond the classroom context. Through this approach, students are expected to gain both technical competence and environmental responsibility. Ultimately, the program contributes to building a scalable and replicable model of technology-based environmental education that supports sustainable community development in wetland regions.

RESEARCH METHODS

The research design used in this community service program is Participatory Technology Development (PTD). This approach emphasizes active user involvement in the co-creation, adaptation, and implementation of technology to ensure relevance, usability, and sustainability within local contexts (Bacon, 2023; Silverman & Patterson, 2021). This design was selected because it allows students and schools to act not only as beneficiaries but also as co-designers of the AI-based waste-sorting system, ensuring that the technology aligns with the specific ecological conditions of wetland environments, characterized by high humidity, sediment contamination, and complex waste composition. The study was conducted at SMAN 4 Banjarmasin, South Kalimantan, which was chosen for its strategic location within a wetland urban ecosystem and its relevance to observed environmental issues, such as river-based waste accumulation and limited digital-based environmental learning practices. This setting provides a realistic context for testing the integration of AI technology into environmental education while addressing local ecological challenges.

Data collection techniques in this study included a combination of pre- and post-test instruments, structured questionnaires, participatory observation, and documentation (Khafsoh & Riani, 2024; Salmona & Kaczynski, 2024). The pre-test and post-test were designed to measure students' AI literacy and eco-entrepreneurial understanding before and after the intervention. At the same time, Likert-scale questionnaires assessed behavioural and attitudinal changes. Participatory observation was conducted during training sessions, AI practice activities, and waste classification simulations using the Gemini AI Vision Recognition system. Documentation was used to record implementation processes, student interactions, and system usage logs. Data analysis was conducted using descriptive statistics, including mean and percentage distributions, and inferential statistics, including a paired-samples t-test or a Wilcoxon signed-rank test, depending on data normality. Additionally, the Normalized Gain (N-Gain) was used to measure the magnitude of learning improvement, providing a structured evaluation of intervention effectiveness.

To ensure data validity and reliability, this study applied a multi-method triangulation approach. Instrument validity was assessed through expert judgment to ensure content relevance and construct alignment with AI literacy and environmental entrepreneurship indicators. Reliability testing was conducted using Cronbach's Alpha to assess the instruments' internal consistency, ensuring measurement stability across respondents. Furthermore, methodological triangulation was applied by comparing results from tests, questionnaires, and observational data to ensure consistency of findings. Source triangulation was also used by involving multiple participant groups, including students, teachers, and facilitators, to strengthen data credibility. This combination of validation strategies ensures that the study's findings are accurate, consistent, and representative of the program's actual implementation, thereby improving students' digital literacy and environmental awareness.

The evaluation framework also integrates technological performance monitoring of the AI-based waste classification system. System logs, user interaction data, and response accuracy from Gemini AI Vision Recognition were analyzed to assess operational effectiveness in real-world conditions. This includes measuring response time, classification accuracy, and user engagement during waste sorting activities. The integration of technological and educational evaluation ensures that both learning outcomes and system performance are assessed comprehensively. This approach strengthens the overall validity of the program by linking educational improvement with practical technological application, ensuring that the PTD model not only enhances cognitive understanding but also supports real environmental problem-solving in wetland ecosystems.

RESULTS AND DISCUSSION

Results

The implementation of the eco-entrepreneurship assistance program using the Participatory Technology Development (PTD) approach at the partner school yielded transformative shifts in students' cognitive capabilities, technical skills, and eco-entrepreneurial self-efficacy. This section systematically evaluated the intervention's empirical findings, contrasting baseline (pre-intervention) conditions with post-intervention outcomes, and then provided a critical synthesis of these findings within the broader academic literature. The session was held on May 11, 2026, at the SMAN 4 Banjarmasin Meeting Hall. This activity was attended by 22 students, 1 principal, 1 teacher, and a service team with the following stage details.

Systematic Evaluation of Program Implementation Stages

Socialization: Equalizing Perceptions and Building Awareness, Prior to the intervention, baseline observations indicated a profound "awareness-action gap" among participants. Although students possessed high familiarity with digital entertainment tools, their understanding of the ecological vulnerabilities of their local wetland ecosystem was highly superficial. Waste was universally perceived as an organic nuisance or "dirt" (lumpur/sampah) with zero economic utility, leading to passive, reactive disposal habits.

Figure 3 Participatory Socialization Session on Circular Economy Frameworks

To address this baseline condition, the socialization phase introduced the core tenets of the Circular Economy. By utilizing interactive, dialogic panel discussions, the service team successfully initiated a cognitive shift (mindset shifting). The direct output of this stage was the formal signing of a joint commitment pact between the academic team, school administrators, and student representatives. This commitment served as the institutional foundation for the program, ensuring high participation rates and structural support for the subsequent technical phases.

Training: Applied AI Literacy Knowledge Transfer

At the pre-training stage, students exhibited negligible literacy regarding applied Artificial Intelligence (AI). While aware of consumer-grade AI (such as ChatGPT), none of the participants understood how machine vision, object detection, or convolutional image labeling operated.

Figure 4. Practice using tools

Mechanics of Machine Vision: Students practiced capturing images of plastic polymers (specifically PET, HDPE, and LDPE) and observed how AI models extract edge features, textures, and density.

Contextual Dataset Enrichment: To optimize the algorithm for local constraints, the training utilized a custom, localized dataset representing the actual "dirty," "mossy," and "sediment-contaminated" waste characteristics retrieved directly from the wetland canals surrounding the school. This approach ensured that the AI model became highly familiar with the challenging physical anomalies of swamp waste, rather than relying on clean, idealized laboratory datasets.

Empowering Eco-Entrepreneurship: this hands-on interaction directly enhanced students' entrepreneurial self-efficacy. By demystifying the technology, students shifted from feeling intimidated by AI to recognizing it as an accessible operational tool capable of driving high-efficiency green micro-enterprises.

Technology Application: Execution of Solutions with AI Prototypes

Before the deployment of the prototype, waste sorting activities at the partner school were conducted manually, resulting in low classification accuracy, slow processing time, and high physical discomfort due to the wet and organic nature of wetland waste. These limitations reduced operational efficiency and increased resistance among participants during sorting activities.

Figure 6. Prototype Student's Products

Figure 6 illustrates the student-developed prototype outputs produced during the implementation stage. The figure highlights the practical application of the AI-based waste sorting system in an educational setting, showing how students engaged with the prototype to classify waste materials. It also reflects the transition from theoretical understanding to hands-on practice, where students interacted directly with the system interface and generated classification results as part of the learning process.

The execution stage resolved previous manual bottlenecks by implementing a cloud-native, AI-based waste sorting system designed for the complex riverine conditions of Banjarmasin, including high moisture content and organic sediment contamination. The system achieved a verified classification accuracy of 92% in automatic material labeling and reduced processing latency to an average of 1.5 seconds per object. These results indicate that a lightweight cloud-based architecture can deliver high-precision sorting performance, even when operated through standard low-tier student smartphones, thereby improving accessibility without reducing computational effectiveness.

To evaluate the empirical impact of the program on participant learning outcomes, a paired pre-test and post-test design was applied using a 10-question assessment instrument. The quantitative outcomes are presented in Table 3.

Table 3. Comparative Matrix of Pre-test and Post-test Performance Metrics

Evaluation Categories	Classroom Accuracy	Average Participant Score	Remarks
Pretest	59%	5.673	Initial understanding of the basic concepts of waste and AI.
Post-test	63%	7.766	Increased understanding after mentoring sessions.

The data reveals a statistically significant cognitive improvement. The classroom accuracy rate rose from 59% to 63%, while the average individual score experienced a substantial 36.9% increase, climbing from 5.673 to 7.766.

Analyzing the individual test items reveals that the most prominent cognitive leap occurred in questions regarding "AI's capacity to evaluate the economic feasibility of degraded wetland raw materials." On this specific metric, post-test accuracy soared to 73%. This finding indicates that the interactive, real-time feedback loop provided by the Gemini AI API (which provides immediate explanations on how to clean, prep, and value sediment-covered plastics) acted as an effective cognitive scaffold. Students did not merely memorize classifications; they developed a deep, operational understanding of how material degradation affects market value in a circular economy.

Discussion

The success of this intervention demonstrates both alignment and divergence when compared with existing literature on youth digital empowerment and environmental technology adoption. In terms of similarities, the increase in students' eco-entrepreneurial self-efficacy supports the emphasized that hands-on digital tools can significantly reduce psychological barriers toward green entrepreneurship (Cocu et al., 2025; Raza et al., 2025). The high system performance, with a reported 92% classification accuracy in humid wetland conditions, is also consistent highlighted the importance of localized machine vision training for waste in tropical and high-moisture environments (Li et al., 2021; Tulsi et al., 2025). These similarities confirm that integrating practical AI tools into environmental education strengthens both cognitive and behavioral outcomes. However, unlike prior studies that primarily focus on conceptual literacy improvement, this program demonstrates a stronger transition from knowledge to action through embedded technological and entrepreneurial integration within a single learning ecosystem.

A key difference from previous research lies in how ecological literacy is operationalized. that although students can achieve high conceptual understanding of waste management, reaching up to 85.71% proficiency, this understanding rarely translates into real behavioral or economic action (Asmara et al., 2026; Khairuddin et al., 2024). In contrast, this study successfully bridges that gap by integrating real-time economic valuation features within the AI-based waste classification interface. This design transforms waste identification into an immediate value-based learning experience, which directly connects environmental awareness with entrepreneurial motivation. This approach reduces the awareness-action gap described where digital literacy among youth tends to remain consumptive rather than productive (Jimenez et al., 2021; Wang et al., 2022). The findings indicate that embedding economic feedback into environmental learning systems is a critical factor in converting ecological knowledge into tangible behavioral change.

From a state-of-the-art perspective, this study contributes a significant shift from hardware-dependent AI waste management systems to fully cloud-native, mobile-based solutions. Previous approaches, as described often rely on physical sensors and embedded microcontroller systems that are costly and less adaptive to wetland environments characterized by high humidity and sediment contamination (Diepeveen & Pinet, 2022; Wang et al., 2022). In contrast, this intervention demonstrates that a cloud-based AI vision system using smartphone cameras can achieve comparable or even higher accuracy levels, reaching approximately 92%, while eliminating the need for specialized hardware. This innovation enhances accessibility and scalability, particularly in resource-limited educational environments. Furthermore, the Participatory Technology Development (PTD) framework enables socio-technical co-creation, positioning students not only as users but also as contributors to system improvement through continuous data input, aligning with the concept of participatory digital ecosystems (Degen et al., 2025; Mihale-Wilson & Carl, 2024).

The socio-technical integration in this study also introduces a novel contribution to environmental education systems. By involving students in generating and refining localized waste image datasets, the system evolves into a community-driven adaptive model. This participatory feedback loop improves algorithmic performance while simultaneously increasing student engagement and ownership of the technology. Such an approach extends beyond conventional top-down implementations and creates a dynamic learning environment where ecological and technological knowledge evolve simultaneously. This model demonstrates how digital tools can be effectively localized to address specific environmental challenges in wetland ecosystems while also fostering innovation-oriented behavior among students.

In terms of empirical outcomes, the student response data further validate the effectiveness of this intervention. The high satisfaction levels and strong engagement indicators, including 88.2% achievement in AI and waste understanding and 91.0%

perceived benefit, indicate that the program successfully enhances both cognitive and affective learning domains. The fact that 93.1% of participants were first-time AI users further highlights the transformative nature of the intervention. These results confirm that integrating AI-based tools into environmental education significantly improves both technological literacy and entrepreneurial motivation. This also indicates that experiential digital learning is more effective than conventional instruction in building long-term behavioral intention toward sustainable environmental practices.

Overall, the theoretical implication of this study is the reinforcement of experiential learning theory within AI-driven environmental education, where knowledge acquisition is strengthened through direct interaction with real-world systems. Practically, the intervention demonstrates a scalable model for integrating AI literacy, environmental management, and circular economy principles in secondary education settings. The main contribution of this research lies in the development of a participatory, cloud-based AI waste classification system that bridges the gap between environmental awareness and entrepreneurial action. This study also provides a replicable framework for other wetland regions, offering a sustainable model for transforming digital literacy into ecological problem-solving capacity and youth-driven green innovation ecosystems.

CONCLUSION

This study concludes that the structural gap between youth digital literacy and real ecological action in wetland environments can be effectively reduced through a participatory, AI-integrated learning model. The main findings show that integrating cloud-native machine vision with a circular economy-based valuation system successfully transforms students from passive technology users into active eco-entrepreneurs, with high classification performance (92%) and fast processing speed on standard smartphones. These results demonstrate that contextualized AI applications can enhance environmental awareness, entrepreneurial motivation, and practical waste management behavior at the school level, making the model scalable for broader educational and community implementation. The study also confirms that embedding economic value recognition within environmental learning strengthens behavioral transformation compared to conventional theoretical approaches. However, limitations remain in network dependency, visual-only classification, and dataset localization, which may affect system performance in different ecological contexts. Therefore, it is recommended that future implementations adopt hybrid edge-cloud architectures and multi-modal sensor integration to improve system robustness and accuracy. Further research should also focus on longitudinal studies to evaluate the sustainability of student-led eco-entrepreneurship initiatives, their real economic impact, and long-term behavioral change in environmental practices across wider regional and socio-economic settings.

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REFERENCES

Adomako, R. B., Boakye, P. B., & Salapki, A. (2025). Tech-Driven Governance for Sustainability: Enhancing Environmental Disclosure Through Corporate Governance and Innovation in Emerging Market. *SN Business & Economics, 5*(7), 86. https://doi.org/10.1007/s43546-025-00852-5

Asmara, A. S., Yusuf, Y., Prawiyogi, A. G., Zonyfar, C., Alhamssyah, M. A., & Alfarid, M. N. (2026). Profiling Numeracy Literacy Among Ninth-Grade Students: Empirical Evidence From Junior Secondary Education. *Infinity Journal, 15*(1), 291–318. https://doi.org/10.22460/infinity.v15i1.p291-318

Bacon, N. (2023). Community Service Writing: Problems, Challenges, Questions. In *Writing the Community* (pp. 39–55). Routledge. https://doi.org/10.4324/9781003448853-4

Boffardi, R., De Simone, L., De Pascale, A., Ioppolo, G., & Arbolino, R. (2021). Best-Compromise Solutions for Waste Management: Decision Support System for Policymaking. *Waste Management, 121*, 441–451. https://doi.org/10.1016/j.wasman.2020.12.012

Cao, Z., Lai, Z., Bilawal Khaskheli, M., & Wang, L. (2025). The Risk of Global Environmental Change to Economic Sustainability and Law: Help From Digital Technology and Governance Regulation. *Sustainability, 17*(15), 7094. https://doi.org/10.3390/su17157094

Cocu, A., Pecheanu, E., Susnea, I., Dingli, S., Istrate, A., & Tudorie, C. (2025). Technology-Enabled Learning for Green and Sustainable Entrepreneurship Education. *Administrative Sciences, 15*(2), 45. https://doi.org/10.3390/admsci15020045

Degen, K., Lutzens, R., Beschorner, P., & Lucke, U. (2025). Public Education Data at the Crossroads of Public and Private Value Creation: Orchestration Tensions and Stakeholder Visions in Germany's Emerging National Digital Education Ecosystem. *Electronic Markets, 35*(1), 19. https://doi.org/10.1007/s12525-024-00752-w

Diepeveen, S., & Pinet, M. (2022). User Perspectives on Digital Literacy as a Response to Misinformation. *Development Policy Review, 40*, e12671. https://doi.org/10.1111/dpr.12671

Eresanya, O. I., Babaniyi, B. R., Ojo, O. T., & Olorunfemi, K. O. (2025). Future Challenges and Opportunities for Wetland Preservation. In *Wetland Ecosystems: Conservation Strategies, Policy Management and Applications* (pp. 387–413). Springer. https://doi.org/10.1007/978-3-031-91982-4_18

Esposito, P., Antonucci, G., Palozzi, G., & Fijałkowska, J. (2025). Cognitive Systems for Improving Decision-Making in the Workplace: An Explorative Study Within the Waste Management Field. *Management Decision, 63*(10), 3408–3430. https://doi.org/10.1108/MD-08-2023-1320

Gabriel, P. O., Yusuf, T. B., Omekara, C. L., Ishola, O. J., Ogungbenro, A. M., & Obiribea-Addo, P. (2024). Sustainable Consumption Patterns, Non-Biodegradable Wastes Reduction and Environmental Protection in Kwara State, Nigeria. In *2024 International Conference on Science, Engineering and Business for Driving Sustainable Development Goals (SEB4SDG)* (pp. 1–10). IEEE. https://doi.org/10.1109/SEB4SDG60871.2024.10629769

Gutierrez-Lopez, J., McGarvey, R. G., Costello, C., & Hall, D. M. (2023). Decision Support Frameworks in Solid Waste Management: A Systematic Review of Multi-Criteria Decision-Making with Sustainability and Social Indicators. *Sustainability, 15*(18), 13316. https://doi.org/10.3390/su151813316

Husamah, H., Rahardjanto, A., Permana, T. I., & Shukri, A. A. M. (2025). Integration of Digital Technologies in Environmental Education: A Systematic Review of Trends, Impacts, and Future Directions. *Jurnal Varidika*, 30–47. https://doi.org/10.23917/varidika.v37i1.9908

Iqbal, Q., & Ahmad, N. H. (2021). Sustainable Development: The Colors of Sustainable Leadership in Learning Organization. *Sustainable Development, 29*(1), 108–119. https://doi.org/10.1002/sd.2135

Jimenez, C., Clark, L. S., Kennedy, H., Nisle, S., Engle, C., Matyasic, S., & Anyon, Y. (2021). The Art of Youthful Restraint: Negotiating Youth-Adult Relations in Digital Media Literacy. *Learning, Media and Technology, 46*(2), 190–203. https://doi.org/10.1080/17439884.2021.1888118

Khafsoh, N. A., & Riani, N. (2024). Implementation of Participatory Action Research (PAR) in Community Service Program. *Jurnal Pengabdian Masyarakat, 5*(1), 237–253. https://doi.org/10.32815/jpm.v5i1.2034

Khairuddin, D., Ali, N. H. N., Kamaruding, M., & Ismail, N. N. (2024). Students' Perception and Exploring Technological Roles in Solid Waste Engineering and Management Education. *International Journal of Sustainable Construction Engineering and Technology, 15*(1), 287–298. https://doi.org/10.30880/ijscet.2024.15.01.020

Lair, A., Mansuy, M., Romand, C., Oberti, O., Pradels, C., Barina, G., Denoun, T., Venturini, M., & Trommsdorff, C. (2024). Enhancing Landfill Efficiency to Drive Greenhouse Gas Reduction: A Comprehensive Study on Best Practices and Policy Recommendations. *Waste Management & Research, 42*(10), 889–900. https://doi.org/10.1177/0734242X241270951

Lakhouit, A. (2024). Mitigating Landfill Emissions Strategies for Effective Waste Management in Tabuk. *Cleaner Waste Systems, 9*, 100187. https://doi.org/10.1016/j.clwas.2024.100187

Li, J., Zhu, X., Li, Y., Tong, Y. W., Ok, Y. S., & Wang, X. (2021). Multi-Task Prediction and Optimization of Hydrochar Properties From High-Moisture Municipal Solid Waste: Application of Machine Learning on Waste-to-Resource. *Journal of Cleaner Production, 278*, 123928. https://doi.org/10.1016/j.jclepro.2020.123928

Lo, N. P.-K. (2024). The Confluence of Digital Literacy and Eco-Consciousness: Harmonizing Digital Skills With Sustainable Practices in Education. *Platforms, 2*(1), 15–32. https://doi.org/10.3390/platforms2010002

Marco-Lajara, B., Zaragoza-Sáez, P., Martínez-Falcó, J., & Ruiz-Fernández, L. (2022). The Effect of Green Intellectual Capital on Green Performance in the Spanish Wine Industry: A Structural Equation Modeling Approach. *Complexity, 2022*, 6024077. https://doi.org/10.1155/2022/6024077

Mihale-Wilson, C., & Carl, K. V. (2024). Designing Incentive Systems for Participation in Digital Ecosystems-An Integrated Framework. *Electronic Markets, 34*(1), 16. https://doi.org/10.1007/s12525-024-00703-5

Mohanaprasadh, S. V., Singh, P., & Bahukhandi, K. D. (2022). Disposal of Non-Biodegradable Waste Using Eco-Friendly Methods. In *Environmental Pollution and Natural Resource Management* (pp. 345–363). Springer. https://doi.org/10.1007/978-3-031-05335-1_20

Mukhopadhyay, C. (2022). Climate Change Adaptation and Built Environment Resilience: East Kolkata Wetland Strategies. *Built Environment, 48*(4), 594–612. https://doi.org/10.2148/benv.48.4.594

Nag, S., Vagh, S. B., Dulay, K. M., Snowling, M., Donolato, E., & Melby-Lervåg, M. (2024). Home Learning Environments and Children's Language and Literacy Skills: A Meta-Analytic Review of Studies Conducted in Low- and Middle-Income Countries. *Psychological Bulletin, 150*(2), 132. https://doi.org/10.1037/bul0000417

Nile, B. K., Al-Saadi, R. J. M., Abdulameer, L., Al Maimuri, N. M. L., & Al-Dujaili, A. N. (2025). Climate Change Impacts on River Hydraulics: A Global Synthesis of Hydrological Shifts, Ecological Consequences, and Adaptive Strategies. *Water Conservation Science and Engineering, 10*(2), 48. https://doi.org/10.1007/s41101-025-00375-y

Orhorhoro, E. K. (2025). A Review of Plastic Waste Management for a Sustainable Environment: Composition and Approaches. *European Journal of Sustainable Development Research, 9*(3). https://doi.org/10.29333/ejosdr/16359

Raza, A., Ali, J. K., & Rozaimie, A. (2025). Impact of Ecological Innovation, Entrepreneurial Mindset, and Green Entrepreneurial Orientation on Entrepreneurial Self-Efficacy and Digital Entrepreneurial Intention in the Context of Saudi Arabia. *Journal of Advanced Research in Business and Management Studies, 41*(1), 108–123.

Sahoo, S., Kumar, A., & Upadhyay, A. (2023). How Do Green Knowledge Management and Green Technology Innovation Impact Corporate Environmental Performance? Understanding the Role of Green Knowledge Acquisition. *Business Strategy and the Environment, 32*(1), 551–569. https://doi.org/10.1002/bse.3160

Salmona, M., & Kaczynski, D. (2024). Qualitative Data Analysis Strategies. In *How to Conduct Qualitative Research in Finance* (pp. 80–96). Edward Elgar Publishing. https://doi.org/10.4337/9781803927008.00012

Shafiee Rad, H. (2025). Reinforcing L2 Reading Comprehension Through Artificial Intelligence Intervention: Refining Engagement to Foster Self-Regulated Learning. *Smart Learning Environments, 12*(1), 23. https://doi.org/10.1186/s40561-025-00377-2

Shakina, E., Parshakov, P., & Alsufiev, A. (2021). Rethinking the Corporate Digital Divide: The Complementarity of Technologies and the Demand for Digital Skills. *Technological Forecasting and Social Change, 162*, 120405. https://doi.org/10.1016/j.techfore.2020.120405

Sharma, B. K., Jha, A., Bhalani, D., Pillai, S. A., Pal, S., Patil, K., & Nagaraj, K. (2025). Advancements in Bio-Resource-Based Polymers and Composites: Sustainable Alternatives to Non-Biodegradable Plastics for a Greener Future: A Review. *Current Green Chemistry*. https://doi.org/10.2174/0122133461372269250503082219

Silverman, R. M., & Patterson, K. (2021). Qualitative Research Methods for Community Development. *Routledge*. https://doi.org/10.4324/9781003172925

Tian, N., & Wang, W. (2024). Innovative Pathways for Collaborative Governance in Technology-Driven Smart Communities. *Sustainability, 17*(1), 98. https://doi.org/10.3390/su17010098

Tulsi, A., Momin, A., & Ayres, V. (2025). Moisture Prediction in Chicken Litter Using Hyperspectral Data and Machine Learning. *Smart Agricultural Technology, 11*, 101058. https://doi.org/10.1016/j.atech.2025.101058

Wang, J., Liu, C., & Cai, Z. (2022). Digital Literacy and Subjective Happiness of Low-Income Groups: Evidence from Rural China. *Frontiers in Psychology, 13*, 1045187. https://doi.org/10.3389/fpsyg.2022.1045187

Wohl, E., Castro, J., Cluer, B., Merritts, D., Powers, P., Staab, B., & Thorne, C. (2021). Rediscovering, Reevaluating, and Restoring Lost River-Wetland Corridors. *Frontiers in Earth Science, 9*, 653623. https://doi.org/10.3389/feart.2021.653623