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Empowering Circular Economy Education Through Student-Led Sustainability Initiatives in Rural Sarawak

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Climate education in rural Malaysian communities is often constrained by poor digital infrastructure and the limited availability of locally relevant examples of sustainability concepts such as the circular economy (CE). The purpose of this study was to evaluate a student-led service-learning programme in Kampung Assum, Sarawak, designed to embed CE education through experiential learning. Guided by Kolb's learning cycle, three modules were implemented with 24 villagers: upcycling bamboo waste into handmade paper, extracting essential oil from lemongrass, and composting household food waste. Pre- and post-intervention surveys using Likert scales showed knowledge gains of 30–50 percentage points across the modules, with more than 90% of participants reporting increased confidence in applying the new skills. Qualitative reflections further indicated that participants valued hands-on and culturally familiar learning, and many expressed intentions to adopt the practices at home or explore them as potential income-generating opportunities. The findings demonstrate that student-led experiential learning can effectively bridge climate education gaps in rural Malaysia by linking CE concepts to daily livelihoods, while also offering universities a practical model for embedding sustainability education into curricula and enhancing community resilience.

1. Introduction

Education has long been recognised as a cornerstone of sustainability efforts, and international policy frameworks increasingly highlight its central role. UNESCO (2020), for example, positions learner empowerment as essential for informed climate action, while the Intergovernmental Panel on Climate Change (IPCC, 2022) underscores education's contribution to building adaptive capacity and resilience. These perspectives suggest that pedagogy must move beyond abstract ideas and provide opportunities for hands-on engagement. Service-learning offers one such pathway. As Butin (2005) argues, service-learning is not only an academic practice but also a civic one, capable of reshaping higher education by connecting classroom learning to real-world action. In Malaysia, this vision has been translated into practice through the SULAM framework, which encourages students to apply their knowledge directly in community settings (Saad et al., 2024).

Building on this, recent scholarship illustrates how sustainability education can be embedded across disciplines. Pongrácz and Rákosi (2023), for instance, demonstrate its integration within human resource management courses, broadening the reach of sustainability beyond traditional environmental fields. Within this discourse, the circular economy (CE) provides a particularly useful framework. It emphasises reducing waste, optimising resources, and rethinking production–consumption cycles (Kirchherr et al., 2018). CE discussions often remain highly technical, urban-focused, and policy-driven, which makes them less applicable to rural realities (Merli et al., 2018). Recent scholarship further illustrates this orientation, with studies highlighting wastewater bioremediation (Ahmad et al., 2025) and leachate treatment as pathways for advancing CE implementation in industrial and urban contexts (Ilmasari et al., 2022), While such research demonstrates the scientific potential of CE in waste management, it underscores the limited attention given to educational and community-based approaches .To make CE meaningful in such contexts, its principles must be adapted into practical, community-led activities, a task where student participation can play a pivotal role.

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The urgency of this adaptation is even greater in the Global South, where persistent inequality, linguistic diversity, and uneven digital infrastructure restrict access to sustainability education. Mochizuki and Fadeeva (2010) emphasise how resource limitations and structural inequities impede the mainstreaming of sustainability into educational systems. Sterling et al. (2017) likewise highlight how language and technological divides reduce participation. While awareness campaigns and curricular initiatives on CE are spreading, they often remain abstract and disconnected from everyday realities. Unless translated into local practices, such efforts risk limited uptake and minimal behavioural change (Leal Filho et al., 2018).

Malaysia provides a relevant example of this gap. National frameworks such as the Malaysia Education Blueprint 2013–2025, the National Policy on Climate Change (2009), and the Roadmap to Zero Single-Use Plastics (MESTECC, 2018) emphasise environmental literacy, green skills, and behavioural shifts. However, rural communities, many of whom rely on oral traditions, have limited literacy, and depend directly on natural resources for their livelihoods, rarely receive interventions that reflect their needs or contexts. Existing initiatives are usually expert-driven and delivered in Bahasa Malaysia or English, with little cultural or dialectal adaptation. As a result, rural participants often remain passive recipients rather than active contributors to sustainability knowledge (Azman et al., 2020).

Higher education institutions (HEIs) are well placed to respond to this challenge. By embedding service-learning into their curricula, HEIs can align academic objectives with community priorities. Butin (2005) emphasises that service-learning combines academic growth with civic responsibility, creating opportunities for meaningful engagement. In Malaysia, this orientation has been formalised through the SULAM initiative, which provides a structured framework for students to work alongside communities (Saad et al., 2024). When such efforts are guided by Kolb's experiential learning model (Kolb, 1984) and the sustainability competencies articulated in frameworks such as the European Commission's GreenComp (Bianchi et al., 2022), they not only transfer technical knowledge but also cultivate behavioural dispositions that underpin long-term sustainable practices.

Despite its growing presence in Malaysian higher education, evidence of service-learning's impact on community learning outcomes remains limited. Much of the existing research emphasises student development and reflective practice (Azman et al., 2020). Saad et al. (2024) similarly note that evaluation tends to privilege student perspectives while overlooking community benefits. To address this gap, the present study evaluates a student-led circular economy (CE) education programme delivered in a rural community. The intervention comprised three modules; upcycling bamboo waste into handmade paper, extracting lemongrass essential oil, and composting household food waste. Using a pre–post mixed-methods design, the study assesses shifts in participants' knowledge, confidence, and behavioural intentions, while exploring how experiential, locally grounded learning can strengthen sustainability education in rural Malaysia.

2. Methodology

This study adopted a quasi-experimental pre–post design to examine the impact of a student-led experiential climate education programme on participants' knowledge, confidence, and behavioural intention. Each module was facilitated by trained undergraduate students as part of a service-learning project, with the aim of combining knowledge transfer and skills practice in a community setting.

The programme consisted of three 90-minute hands-on modules:

i. Composting – Introduction to composting principles, processes, and applications.
ii. Essential Oil Extraction – Demonstration and guided practice of lemongrass oil distillation for the use of natural and sustainable products.
iii. Bamboo Paper Making – Conversion of bamboo waste into artisanal paper products using traditional and modern methods.

The programme design was grounded in Kolb's Experiential Learning Theory (1984), with each module intentionally aligned to the four stages of Kolb's cycle. Participants first engaged in Concrete Experience through hands-on activities such as composting, essential-oil distillation, and bamboo papermaking. This was followed by Reflective Observation, where guided discussions enabled participants to analyse their experiences and identify key learning points. During Abstract Conceptualisation, facilitators linked these reflections to circular-economy and sustainability principles, strengthening the connection between practice and theory. Finally, in Active Experimentation, participants planned how to apply the acquired skills in their homes or micro-enterprises, promoting the translation of learning into real-world practice.

The programme was conducted in Kampung Assum, a rural Bidayuh village in Sarawak, Malaysia. The village head nominated the participants through the purpose sampling 33 in collaboration with the village head and community representatives. Inclusion criteria were: (i) age ≥ 15 years, (ii) residence in Kampung Assum, and (iii) willingness to participate in all workshop modules. However, only a total of 24 participants attended, comprising youth, working adults, and retirees. The absence of the remaining villager was due to various personal reasons. The intervention comprised three modules and an interactive eco-bingo activity (1 hour) was

conducted as a supplementary engagement tool to reinforce learning, but it was not considered a formal module. The evaluation used a pre–post survey to measure four domains: (1) knowledge, (2) self-eficacy, (3) behavioural intent and (4) satisfaction. Matched pre–post items were administered only for modules where participants completed both sessions (e.g., Composting). Post-event reflections were used to capture qualitative feedback on perceived relevance, learning experience, and suggestions for improvement.

2.1 Data Collection Instrument

The survey items shown in Table 1 were adapted from previously validated instruments**,** particularly the I-SABE scale developed by Ruano et al. (2022), which was designed to assess perceptions, behaviour, self-efficacy, and knowledge/skills in evidence-based practice. Content validity was further established through expert review to ensure relevance and appropriateness to the local context. Reliability testing in the present study demonstrated acceptable internal consistency, with Cronbach's alpha values exceeding the recommended threshold ($\alpha > 0.70$) across domains. The instrument also collected demographic data and attendance at the modules. Post-event reflections were written on-site and collected immediately after each session.

Table 1: Summary of Questionnaire Constructs

Variable	Measurement Items
Knowledge	Objective or perceived understanding of topic content
Self-efficacy	Confidence to perform practice independently or with assistance
Behavioural intent	Planned follow-up actions (e.g., try again, teach others, reduce certain purchases, explore other uses)
Satisfaction	Clarity of presentation, quality of demonstration, value of hands-on activities
Open-ended feedback	Relevance, applicability, and suggestions for improvement

2.2 Data Collection Procedure

The surveys were administered in paper format and face to face on the site. Each participant completed the pre-survey before the session began and the post-survey immediately after. For Composting, the matched data allowed for statistical comparison. Reflections were gathered from the students on post-event to supplement quantitative findings.

2.3 Data Analysis

2.3.1 Quantitative Analysis

The data from the pre-post survey were entered into SPSS Statistics (version 29) for analysis. Descriptive statistics (mean, standard deviation and percentage change) were calculated to summarise participant characteristics and responses for each survey item. To evaluate changes in knowledge and confidence, Wilcoxon signed-rank tests were performed for matched pre–post responses, given the non-normal distribution of ordinal data. The effect sizes (r) were calculated to determine the magnitude of the change, with reference values of 0.1 (small), 0.3 (medium) and 0.5 (large). For behavioural intent, frequency distributions and percentages were used to identify changes in the reported likelihood of the participants to apply the skills learnt.

2.3.2 Qualitative Analysis

Written reflections were transcribed verbatim and coded using a thematic analysis approach (Braun and Clarke, 2006). The analysis followed a six-phase process: (1) familiarisation with the data, (2) generation of initial codes, (3) searching for themes, (4) reviewing themes, (5) defining and naming themes, and (6) producing the report. Coding was conducted manually by two researchers independently, and discrepancies were resolved through discussion to enhance reliability. The themes were identified to capture participant perceptions of the relevance, applicability, and experiential value of the programme.

Results and Discussion

3.1 Quantitative Findings

The quantitative findings were measured based on Knowledge Gains, Self-Efficacy, Behavioural Intent and Satisfaction as shown in the following sub-section.

3.1.1 Knowledge Gains

Participants demonstrated significant knowledge improvements across modules (see Table 2). For composting of food-waste, knowledge scores increased from 56.5 % to 88.3 %, a gain of 31.8 percentage points, $t(23) =$

7.30, p < .001, d = 1.49. For bamboo paper upcycling, scores rose from 43.8 % to 92.9 %, and gain of 49.1 points, t (23) = 15.68, p < .001, d = 3.20. For essential oil extraction, scores increased from 26.0 % to 74.0 %, a gain of 48.0 points, t (23) = 13.72, p < .001, d = 2.80. These effect sizes are all large, suggesting robust improvements in knowledge through experiential activities.

Table 2: Pre and Post Knowledge Scores in Modules

Module	Pre- (%)	Post (%)	Gain (pp)	*t*(23)	*p*	Effect Size (*d*)
Food-Waste Composting	56.5	88.3	+31.8	7.30	< .001 **	1.49
Bamboo Paper Upcycling	43.8	92.9	+49.1	15.68	< .001 **	3.20
Essential Oil Extraction	26.0	74.0	+48.0	13.72	< .001 **	2.80

Note. Values are percentages unless otherwise indicated. t(23) = paired sample t-test. d = Cohen's d for paired samples. Significance set at α = .05 (two-tailed).

3.1.2 Self-Efficacy

Confidence in applying skills increased after all modules. For essential oil extraction, none of the participants expressed confidence before the programme, but all did so after the programme, with 25 % reporting they were "very confident." In composting, 100 % of participants agreed or strongly agreed they understood the process well enough to replicate it. For bamboo paper upcycling, 93 % indicated confidence in producing paper independently.

3.1.3 Behavioral Intent

Behavioral intentions were very high in all modules. All participants in composting and bamboo paper upcycling expressed a willingness to adopt or teach others. For essential oil extraction, all participants indicated a conditional or definitive willingness to produce essential oils if equipment was available. In eco-bingo, 100 % of participants reported intent to change daily habits, particularly through recycling, reuse, and mindful consumption.

3.1.4 Satisfaction

Satisfaction was consistently high. In composting, 95 % strongly agreed that the presentation was clear and 89 % strongly agreed that the demonstration was engaging. For essential oil extraction, 63 % reported enjoying all aspects of the session, and 92 % expressed interest in further learning. In bamboo paper upcycling, 93 % strongly agreed they had learned the process, and 64 % were willing to teach others. In eco-bingo, all participants reported enjoyment and stated the activity motivated habit change.

3.2 Qualitative Findings

Analysis of student reflections revealed three prominent themes: (a) bridge theory and practice, (b) developing facilitation and leadership skills, and (c) emotional and civic growth. Each theme is supported by multiple student quotes and is grounded in recent peer-reviewed literature emphasising the educational power of service-learning for sustainability. Table 3 illustrates that students in this study experienced an enhancement in facilitation and leadership skills, reflecting broader discussions in sustainability education concerning the necessary conditions for transformational leadership. Hill et al. (2024) point out that structural and institutional obstacles often limit such leadership within higher education, emphasizing the value of pedagogical environments, such as service-learning, where these competencies can be nurtured. Correspondingly, Aramburuzabala and Cerrillo (2023) show that service-learning not only merges academic pursuits with civic duty but also bolsters sustainability education. Comparable outcomes are observed by López-Santiago et al. (2024), who reveal that engineering students involved in service-learning developed stronger sustainability values and professional competencies. In the Malaysian context, Jamhari et al. (2024) show that service-learning not only strengthens collaboration and leadership among students but also helps address pressing community needs. Looking more broadly, Rodríguez-Zurita et al. (2025), in a systematic review, confirm that the combination of service-learning and community engagement contributes meaningfully to civic agency and sustainable development outcomes across higher education institutions.

4. Conclusions

This study demonstrated the dual impact of a student-led climate education programme on both community participants and student facilitators. Quantitative results showed substantial improvements in knowledge, with scores increasing by 30 to 50 percentage points between modules and large effect sizes ranging from d = 1.49

to 3.20. All participants reported willingness to adopt at least one sustainability practice, and satisfaction ratings exceeded 90 % agreement across modules. Complementing these findings, qualitative reflections revealed that students bridged theory with practice, developed facilitation and leadership skills, and experienced emotional and civic growth.

Table 3: Themes, Student Reflections, and Supporting Literature

Theme	Illustrative Student Reflections	Supporting Literature / Interpretation
Bridging Theory and Practice	"I realised that what we studied in class could be applied directly in the village." (Student 5) "The villagers asked us questions we never thought about in class and that made me reflect differently on the topic." (Student 14) "When I had to explain composting step by step, I understood it more clearly myself." (Student 9) "Teaching bamboo paper making made me see how simple skills link to larger sustainability ideas." (Student 11)	Service-learning connects classroom knowledge with authentic contexts, reinforcing conceptual understanding. Rodríguez-Zurita et al. (2025) show through a systematic review that service-learning initiatives consistently foster stronger links between theory and practice. Similarly, Alvarez-Vanegas (2024) provides evidence that when students teach others, they consolidate and deepen their own understanding, demonstrating the reciprocal nature of experiential learning.
Developing Facilitation and Leadership Skills	"Explaining composting to elderly participants was challenging but rewarding." (Student 12) "I initially struggled to simplify the content, but when the villages understood, I felt more confident as a facilitator." (Student 7) "I had to adapt my language to suit our audience, something I had not practiced before." (Student 18) "We coordinated among ourselves and took turns presenting when a member of the team was unsure." (Student 20)	Service-based learning fosters communication, leadership, and adaptability skills. Choi et al. (2023) demonstrates that facilitation challenges provide opportunities for students to practice these competencies in real contexts, strengthening their professional readiness. In a related study, Camus (2023) shows that navigating such challenges equips students with transferable soft skills that extend beyond the classroom and into workplace and community settings.
Emotional and Civic Growth	"This project made me feel responsible for helping rural communities adopt sustainable practices." (Student 8) "Seeing the villagers so excited gave me motivation to continue to promote sustainability." (Student 10) "I felt closer to the community because I understood their challenges and hopes." (Student 6) "This experience convinced me that I want to work on community projects after graduation." (Student 15)	Ribeiro et al. (2023) found that students engaged in service-learning activities reported stronger civic awareness and willingness to participate in community initiatives. Similarly, López-Santiago et al. (2024) demonstrated that service-learning improves empathy and sustainability values among engineering students through real-world participation. Payne (2023) further observed that structured service-learning programmes instill a sense of social responsibility, linking academic development with sustainable community impact.

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