Strengthening Youth Ecological Engagement Through Mobile Learning: An Experimental Study with Eco-Facilitator Coaching

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Abstract

Rapid environmental degradation in urban areas has intensified the demand for educational strategies that can foster sustained ecological engagement among marginalized youth. This study evaluates the effectiveness of a hybrid intervention integrating a mobile learning application, *JawaraEco*, with eco-facilitator coaching in enhancing multidimensional ecological engagement. An experimental design was implemented, involving 232 urban youth from four densely populated subdistricts in Jakarta, randomly assigned to either an experimental group (receiving access to the app and coaching) or a control group (no intervention). Data were collected through in-app behavioral metrics and a validated ecological engagement scale, encompassing cognitive, emotional, behavioral, and continuity dimensions. Statistical analyses, including paired and independent samples t-tests as well as two-way ANOVA, revealed significantly greater gains across all dimensions in the experimental group. These findings demonstrate that combining mobile learning with structured human facilitation fosters more robust and sustained ecological behaviors. The study contributes practical insights for scalable implementation in schools, community programs, and local governance, while also offering theoretical support for technology-supported, socially embedded environmental learning ecosystems.

Keywords: *Youth Ecological Engagement; Mobile Learning Intervention; Eco-Facilitator Coaching; Environmental Behavior Change; Experimental Environmental Education.*

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A. INTRODUCTION

Rapid urbanisation has accelerated a range of ecological pressures in urban areas, as the expansion of built environments intensifies heat island effects, elevates pollution levels, and disrupts ecological connectivity (Karimi et al., 2023; Li et al., 2021; Najafzadeh et al., 2021). Global waste generation has already surpassed 2.1 billion tons annually and is projected to reach 3.4 billion tons by mid-century, with major cities producing some of the highest per-capita volumes (Almulhim & Cobbinah, 2023). At the same time, declining vegetation cover and species richness continue to undermine urban biodiversity (Aboulnaga et al., 2024; Velasco & Luna-Aranguré, 2024). Taken together, these developments highlight the growing need for transformative environmental learning initiatives that specifically engage urban youth.

However, community-based environmental education frequently falls short in fostering long-term behavioural change. Many programmes operate within brief project cycles that limit sustained reinforcement (Quiroz-Cárdenas & López-Gil, 2025), and participants often revert to prior habits once the intervention ends (Barratt

Hacking et al., 2020). Moreover, several initiatives fail to connect with the lived experiences of marginalized youth, making the content less relevant and actionable (Bola & Mapatano, 2021). Structural barriers, such as limited infrastructure and minimal incentives, further constrain their ability to act (Sterling et al., 2022). In-person models also struggle to provide consistent monitoring, largely due to resource shortages and the mobility challenges common among urban youth populations (Hoffman & Moyo, 2020; Mutisya & Kimeu, 2021).

In contrast, mobile learning has gained prominence as an effective means of linking environmental knowledge to concrete actions, especially through features that personalise learning, integrate gamification, and situate content within everyday contexts. Empirical studies show that gamified applications can meaningfully improve environmentally responsible choices and behaviours (Venturi et al., 2025; Li et al., 2024). AI-supported personalisation has also been shown to sustain engagement and deepen understanding of ecological systems (Du et al., 2025). Motivational elements such as challenges and reward structures support habit formation (Rokka, 2025), while localised or context-aware content strengthens users' capacity to apply new behaviours in their own environments (Marques, 2021). Systematic reviews further indicate that immersive and feedback-rich mobile interventions are consistently associated with more durable ecological behavioural changes (Hayes et al., 2023).

Within this digital ecosystem, eco-facilitators play a crucial role by offering the relational and reflective guidance that mobile tools alone cannot provide. Their involvement has been shown to enhance youth motivation and participation (Ngugi et al., 2023), validate their sense of agency and support the continuity of environmentally responsible behaviours (Silva & Duarte, 2020), and strengthen action planning through structured reflection (Khatib & Yeo, 2022). Facilitators also contribute emotional support and peer-based encouragement (Moyo & Thwala, 2021), help contextualise digital content into real-world practices (Santiago & Rivera, 2023), and reinforce feedback loops through personalised coaching (Rokka, 2025).

Despite these advances, the research landscape still exhibits notable gaps. Digital and gamified environmental education continues to demonstrate mixed effectiveness, with many interventions producing temporary gains in awareness but failing to generate stable behavioural change (Baltezarević & Baltezarević, 2025; Radjabov et al., 2025). Similarly, while gamification may elevate short-term motivation, it does not necessarily lead to persistent ecological action (Hayes et al., 2023; Xiong et al., 2024). Another persistent limitation is the scarcity of integrated models that combine mobile platforms with facilitator support and behavioural tracking components essential for linking personalised learning with measurable behavioural outcomes (Du et al., 2025; Khaghanizadeh et al., 2025; Rokka, 2025).

Recent work in environmental education underscores a broader movement toward mobile, gamified, and AI-enhanced systems designed to cultivate ecological engagement among young people. Although these tools often yield improvements in knowledge and motivation (Hayes et al., 2023; Xiong et al., 2024), evidence shows that such gains rarely translate into enduring real-world behavioural change (Baltezarević & Baltezarević, 2025; Radjabov et al., 2025). Emerging studies that incorporate personalised learning pathways demonstrate greater potential for action-oriented outcomes (Du et al., 2025), yet the integration of structured human facilitation remains limited. This study contributes to filling that gap by empirically testing an intervention that combines mobile learning with eco-facilitator mentoring for urban youth.

The research therefore seeks to respond to the longstanding disconnect between environmental understanding and sustained ecological behaviour among young people in urban environments. Although mobile learning platforms have demonstrated benefits across cognitive, emotional, and behavioural domains (Du et al., 2025; Ngugi et al., 2023), patterns of household-level sustainability practices remain uneven without deliberate relational support and guided reflection (Chakraborty et al., 2022; Silva & Duarte, 2020). The central issue addressed in this study is the lack of comprehensive, behaviour-tracking mobile learning frameworks capable of nurturing multi-dimensional ecological engagement cognitive, emotional, behavioural, and continuous across varied urban contexts (Santiago & Rivera, 2023).

Literature Review

Recent research demonstrates that mobile learning enriched with AR, VR, gamification, and interactive modules can substantially enhance environmental knowledge and foster pro-environmental attitudes among youth. VR-based simulations have been shown to strengthen ecological empathy and behavioural intention (Xiong et al., 2024), while AR-assisted tools improve waste-sorting accuracy and motivation (Tamhane et al., 2023). Gamified and interactive applications similarly elevate short-term engagement and cognitive gains (Hayes et al., 2023; Sahranavard et al., 2023). Multi-modal platforms that integrate AI-adapted content and game mechanics further amplify knowledge acquisition and behavioural intent (Du et al., 2025), although real-world action often depends on supportive feedback loops (Rokka, 2025).

Gamification has become a widely used strategy in environmental education, yet its effectiveness in driving lasting sustainable behaviour remains mixed. Missions, rewards, and point-based challenges consistently increase short-term engagement (Hayes et al., 2023), while immersive or VR-based gamified environments primarily enhance behavioural intention rather than actual action (Xiong et al., 2024). Studies also show that excessive reliance on competitive elements may trigger leaderboard fatigue and reduce long-term participation (Tondello et al., 2021). However, collaborative, context-relevant challenges supported by facilitators can foster more durable behavioural practices (Silva & Duarte, 2020), particularly when paired with reflective, meaningful task design (Sahranavard et al., 2023).

Mentoring and facilitator-led support have become increasingly recognized as essential components of Environmental Education, particularly for helping youth translate knowledge into sustained ecological action. Studies show that facilitator-guided sessions significantly strengthen environmental self-efficacy and confidence to adopt sustainable practices (Khatib & Yeo, 2022), while peer-supported models enhance social reinforcement and long-term value internalization (Silva & Duarte, 2020). Hybrid programs that include reflective discussions also help young people maintain pro-environmental routines beyond the intervention period (Ngugi et al., 2023). Moreover, mentors who model eco-friendly behaviours foster stronger agency development, motivating youth to replicate these actions in daily life (Santiago & Rivera, 2023).

Integrated environmental education models that combine mobile learning, real-world action tasks, behaviour-tracking tools, and mentor support have shown stronger and more sustained ecological outcomes among urban youth. Programmes that merge app-based content with peer or facilitator-guided challenges demonstrate higher behavioural continuity and deeper engagement (Silva & Duarte, 2020). Hybrid interventions pairing mobile platforms with weekly mentor sessions similarly report significant reductions in household resource use and enhanced youth agency (Santiago & Rivera, 2023). AI-enabled mobile systems that include adaptive content, mission tracking, and mentoring further boost retention and behaviour adoption (Du et al., 2025), while multi-city pilots confirm that facilitator feedback is key to sustaining real-world eco-actions (Ngugi et al., 2023).

System Description (JawaraEco Mobile Application)

JawaraEco is a mobile-based environmental learning system developed to facilitate measurable sustainability actions among urban youth by integrating digital content with structured eco-facilitator support. This dual approach reflects emerging evidence that mobile platforms combining personalized learning, real-world challenges, and behavioral tracking are significantly more effective when embedded within a mentoring framework (Du et al., 2025; Santiago & Rivera, 2023). Similar outcomes have been observed in Brazil and East Africa, where action-based challenges reinforced through facilitator-guided reflection sessions have led to sustained ecological behaviors among young participants (Silva & Duarte, 2020; Ngugi et al., 2023). Accordingly, *JawaraEco* is purposefully designed to convert environmental knowledge into consistent, verifiable, and socially supported pro-environmental actions.

The application incorporates a range of interactive learning features environmental modules, infographics, short videos, and reflective quizzes to enhance users' cognitive engagement with sustainability content. Research supports that such multimedia designs significantly improve knowledge acquisition and retention, with interactive modules contributing to biodiversity literacy and conceptual clarity (Sahranavard et al., 2023). Visual content such as infographics and videos aids in task-specific accuracy (e.g., waste sorting) (Tamhane et al., 2023), while adaptive quizzes and reflective prompts encourage deeper critical thinking and environmental awareness (Du et al., 2025). Systematic reviews confirm that combining multimedia with structured reflection fosters long-term cognitive engagement among youth (Hayes et al., 2023; Rokka, 2025).

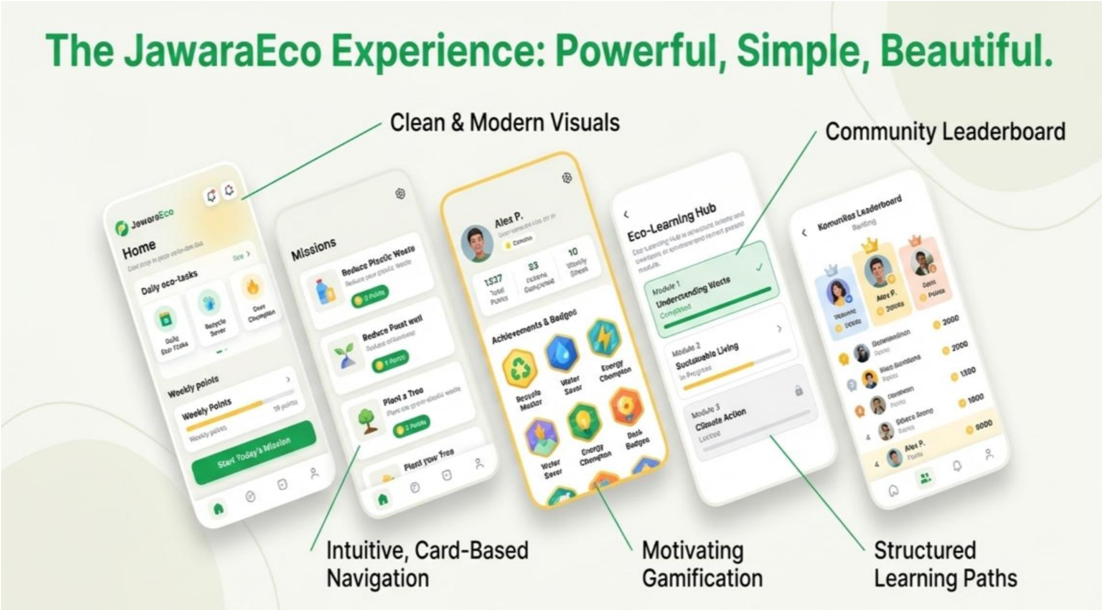

Figure 1. JawaraEco

To bridge the gap between knowledge and action, *JawaraEco* embeds weekly eco-challenges, waste-free living missions, and photo/video-based reporting mechanisms. These real-world tasks, when coupled with visual documentation, have been shown to enhance user accountability and yield tangible sustainability outcomes, such as reductions in household water consumption and improved recycling behaviors (Santiago & Rivera, 2023; Tamhane et al., 2023). Programs that incorporate evidence submission mechanisms also demonstrate stronger habit repetition and mission completion rates (Silva & Duarte, 2020). Furthermore, when combined with mentor-validated reporting and adaptive task design, such systems can promote continuity in behavior and strengthen ecological agency (Du et al., 2025).

Gamification is a core motivational strategy within *JawaraEco*, featuring progress indicators such as points, badges, levels, and leaderboards. These elements are proven to enhance early user engagement and reinforce environmental learning goals (Tondello et al., 2021; Hayes et al., 2023). While badges and levels sustain participation by marking achievement milestones, their long-term efficacy improves when supported by social reinforcement and reflective feedback. Leaderboards, often prone to fatigue effects, have been shown to retain motivational value when linked to relevant, peer-supported challenges (Sahranavard et al., 2023; Tamhane et al., 2023), thereby fostering environmental identity and sustained eco-behavior.

A key feature in figure 1 of *JawaraEco* is the eco-facilitator contact system, which enables personalized mentorship and continuous feedback. This human support component significantly enhances user accountability and motivation, echoing findings that facilitator interaction increases task completion and deepens the internalization of sustainability values (Santiago & Rivera, 2023). Mentor validation contributes to identity formation, especially among marginalized youth (Silva & Duarte, 2020), while tailored encouragement based on behavioral data is associated with higher module completion rates and stronger action consistency (Du et al., 2025).

Weekly mentor check-ins have also been linked to more frequent real-world reporting and reflective learning (Ngugi et al., 2023).

To optimize personalization and monitoring, *JawaraEco* includes a behavioral analytics dashboard that tracks key engagement indicators: App Sessions, Total Minutes, Modules Completed, and Ecofacilitator Contacts. These digital metrics allow facilitators to tailor support and provide targeted feedback based on usage patterns. Similar data-driven approaches in hybrid environmental education settings have been found to improve adherence and engagement (Du et al., 2025). When facilitators respond in real time to user activity logs, participant motivation and task completion increase (Santiago & Rivera, 2023), while consistent tracking enhances behavioral accountability especially in marginalized, resource-constrained urban environments (Ngugi et al., 2023).

B. METHOD

This study utilized a two-group experimental design to assess the effectiveness of the *JawaraEco* intervention in enhancing ecological engagement among marginalized urban youth. Participants were randomly assigned to one of two groups: the experimental group, which accessed the *JawaraEco* mobile learning application supplemented by weekly eco-facilitator coaching, and the control group, which received neither the application nor any facilitation. Over a 10-week intervention period, both groups were systematically monitored to evaluate changes in ecological engagement across four dimensions: cognitive, emotional, behavioral, and habit continuity. This design enabled causal inferences regarding the impact of mobile learning combined with structured mentorship on youth sustainability outcomes.

The study population comprised marginalized urban youth residing in densely populated *Rukun Warga* (RW) slum communities within the Province of DKI Jakarta. A total of 232 participants were recruited through community outreach and eligibility screening. The participants were randomly and evenly assigned into two groups: 116 in the experimental group and 116 in the control group.

Participant engagement with the *JawaraEco* application was quantified using four automatically recorded digital indicators: App_Sessions (total login instances), TotalMinutes (cumulative active usage time), ModulesCompleted (number of fully completed learning modules), and Ecofacilitator_Contacts (frequency of interactions with facilitators via the app). These digital behavioral metrics served as continuous, objective proxies for evaluating the intensity and consistency of user engagement.

To assess ecological engagement, the study employed the Ecological Engagement Assessment Instrument (EAEI), which captures four interrelated dimensions: cognitive understanding, emotional connection, actionable behavior, and habit durability. The cognitive domain was measured using a structured environmental knowledge test. Emotional engagement was assessed via a five-point Likert-scale questionnaire gauging ecological concern and affective attachment. The behavioral and continuity dimensions were evaluated using a portfolio-based rubric in which participants documented their real-world sustainable actions and behavioral consistency over time.

The research followed a structured, multi-stage procedure. During the pre-intervention phase, all participants completed baseline assessments of ecological engagement. The experimental group then received access to the *JawaraEco* application, alongside weekly eco-facilitator support. Throughout the 10-week period, participants completed sustainability challenges and submitted photo/video evidence of their actions, while the system continuously tracked digital engagement. Following the intervention, a comprehensive post-assessment was conducted across both groups to measure cognitive, emotional, and behavioral changes.

Data analysis combined both descriptive and inferential statistical approaches. Descriptive statistics were used to summarize participant characteristics and engagement patterns. Inferential analyses included paired-samples and independent-samples t-tests to examine within- and between-group changes. Additionally, ANCOVA was applied to evaluate the overall intervention effect while controlling for baseline scores. Correlation analyses were conducted to explore associations between digital engagement metrics and ecological behavior outcomes.

C. RESULTS AND DISCUSSION

The study involved 232 marginalized urban youth residing across four regions of Jakarta Central, South, East, and North each contributing 58 participants (25% of the sample), ensuring balanced regional representation. Respondents were divided evenly into 116 control and 116 experimental participants, with proportional distribution maintained across regions. Participants ranged from 16 to 25 years old, with the largest age groups being 19, 23, 25, and 22 years, reflecting a representative spread of late adolescents and young adults. Gender distribution was relatively balanced, comprising 137 males (59.1%) and 95 females (40.9%), with similar proportions in both groups. Among experimental participants, engagement with the JawaraEco application varied in terms of app sessions, total minutes, modules completed, and eco-facilitator contacts. Additionally, ecological involvement was assessed using the Ecological Action Engagement Index (EAEI), capturing cognitive, emotional, behavioural, and long-term sustainability dimensions, providing a comprehensive profile of respondents' ecological literacy and action.

Table 1. Descriptive Statistics of Pre–Post EAEI Scores by Group and Dimension

Dimension	Group	Pre-test Mean (SD)	Post-test Mean (SD)	Mean Change (Δ)	N
Cognitive	Control	36.10 (13.11)	44.99 (14.07)	+8.89	116
	Experimental	37.77 (11.81)	58.30 (12.36)	+20.53	116
Emotive	Control	2.61 (0.21)	2.79 (0.21)	+0.18	116
	Experimental	2.64 (0.23)	3.08 (0.23)	+0.44	116
Behavioural Practice	Control	1.60 (0.44)	1.96 (0.46)	+0.36	116
	Experimental	1.68 (0.46)	2.61 (0.47)	+0.93	116
Temporal Continuity	Control	1.41 (0.41)	1.75 (0.42)	+0.34	116
	Experimental	1.41 (0.39)	2.29 (0.43)	+0.88	116

Prior to the intervention, both groups demonstrated statistically comparable scores across all four EAEI dimensions. As shown in Table 1 and confirmed in Table 2, no significant differences were observed at the pre-test stage (p > .05), indicating baseline equivalence. This foundational similarity strengthens internal validity, ensuring that any subsequent improvements can be attributed to the intervention rather than initial disparities. The balanced pre-test results also confirm the effectiveness of the randomization process and allow confident interpretation of post-intervention changes in both outcome direction and magnitude.

Table 2. Baseline Equivalence (Independent Samples t-test Results for Pre-test)

Dimension	t	df	p	Mean Diff.	95% CI	Conclusion
Cognitive	–1.019	230	.309	–1.67	–4.90 to 1.56	Not significant
Emotive	–0.902	230	.368	–0.03	–0.08 to 0.03	Not significant
Practice	–1.207	230	.229	–0.07	–0.19 to 0.05	Not significant
Continuity	–0.164	230	.870	–0.01	–0.11 to 0.09	Not significant
Total EAEI	–1.699	230	.091	–1.13	–2.44 to 0.18	Not significant

After the 10-week intervention, substantial differences emerged between groups across all EAEI domains. As illustrated in Figure 2, the experimental group demonstrated significantly higher post-test scores compared to the control, especially in the cognitive and behavioral domains. This finding is reinforced by the statistical results, where all p-values were < .001. These improvements suggest that the integration of *JawaraEco* with eco-facilitator coaching yielded meaningful gains in environmental understanding and action. The visual contrast in post-test means provides compelling support for the intervention's educational impact.

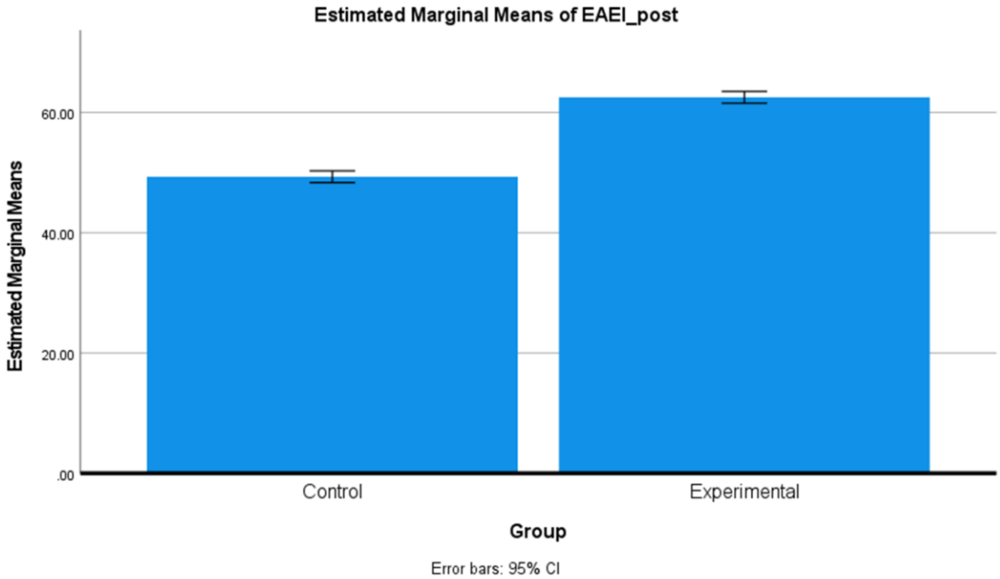

Figure 2. Post-test EAEI Scores by Group

To isolate the magnitude of improvement, gain scores were computed by subtracting pre-test from post-test values. As shown in Table 3, the experimental group achieved significantly higher net gains across all EAEI dimensions. For instance, cognitive gain reached 20.53, more than double the control group's 8.89. Similar patterns were evident in emotive (+0.44 vs. +0.18), behavioral (+0.93 vs. +0.35), and continuity dimensions (+0.88 vs. +0.34). These results, supported by p-values < .001, demonstrate that the hybrid intervention produced not only statistically significant outcomes but also large, practically meaningful behavioral shifts.

Table 3. Gain Score Analysis

Dimension	Control Mean (SD)	Experimental Mean (SD)	Mean Diff.	p
Cognitive	8.89 (18.12)	20.53 (16.06)	–11.64	< .001
Emotive	0.18 (0.05)	0.44 (0.09)	–0.26	< .001
Practice	0.35 (0.13)	0.93 (0.18)	–0.58	< .001
Continuity	0.34 (0.13)	0.88 (0.19)	–0.54	< .001
Total EAEI	8.03 (4.81)	20.11 (4.28)	–12.08	< .001

To examine whether outcomes differed by geographic context, a two-way ANOVA (Group × Region) was conducted. As presented in Table 4, the main effect of Group was highly significant ($F = 364.53$, $p < .001$), confirming the robustness of the intervention. While a minor regional effect was observed ($F = 2.73$, $p = .045$), the interaction term was non-significant ($F = 1.33$, $p = .265$). This finding, visualized in Figure 3, reveals that the intervention's efficacy was consistent across all regions, suggesting that the *JawaraEco* system and facilitator model function effectively regardless of local contextual variation.

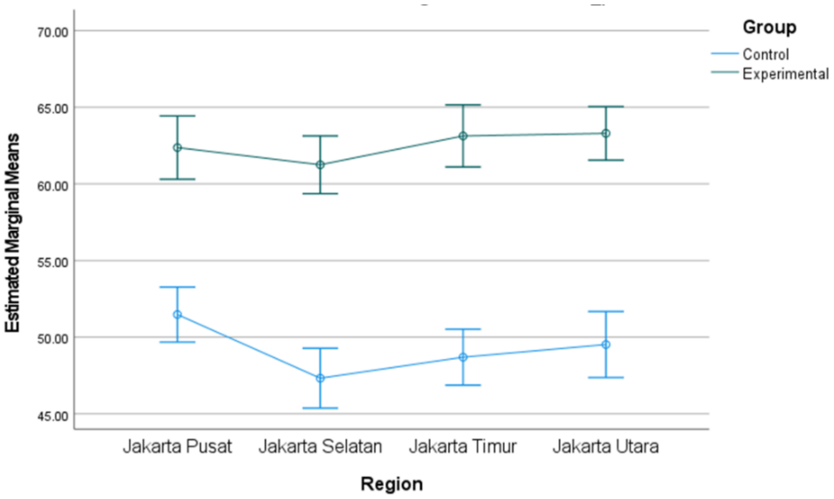

Figure 3. Interaction Plot of Group × Region for Post-test EAEI

Table 4. Two-Way ANOVA (Group × Region) for Post-test EAEI

Source	SS	df	MS	F	p	Interpretation
Group	10005.33	1	10005.33	364.53	< .001	Significant
Region	224.66	3	74.89	2.73	.045	Significant
Group × Region	109.61	3	36.54	1.33	.265	Not significant
Error	6148.23	224	27.45	–	–	–

To consolidate the overall intervention effect, a comparative summary across pre-test, post-test, and gain scores was visualized in Figure 4. The chart reveals a clear divergence between experimental and control groups after the intervention, especially in total EAEI scores. These visuals complement the statistical evidence and affirm that the intervention resulted in both breadth (across all dimensions) and depth (in magnitude of change) of ecological engagement. The strong upward trend in the experimental group underscores the efficacy of combining mobile learning with relational coaching for achieving sustained behavioral outcomes.

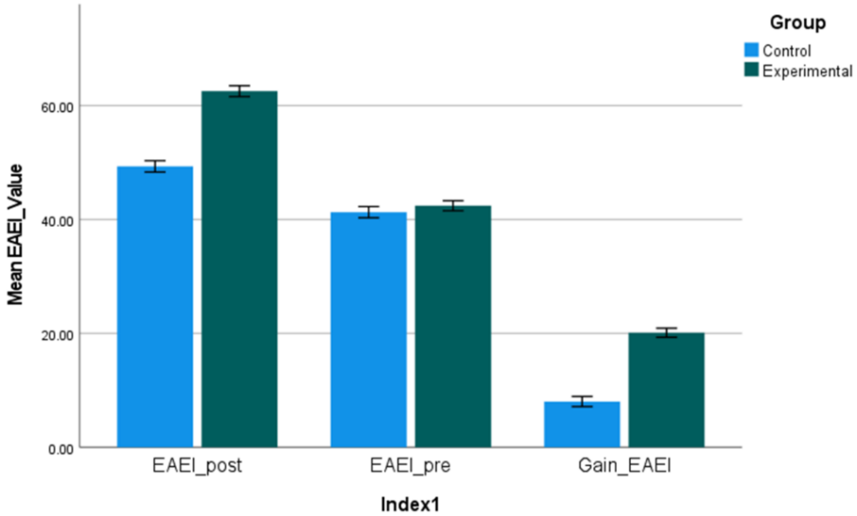

Figure 4. Total EAEI Comparison Across Pre-test, Post-test, and Gain Score

Overall, the results strongly support the conclusion that *JawaraEco*, when integrated with structured eco-facilitator guidance, substantially enhances ecological engagement among marginalized urban youth. The convergence of evidence across descriptive, inferential, and visual analyses reinforces the intervention's validity and generalizability. Importantly, the improvements spanned knowledge, emotion, behavior, and habit indicating comprehensive transformation. These findings not only contribute to empirical literature in technology-enhanced environmental education but also offer a scalable model for implementation in policy, school, and community-based programs targeting sustainable youth behavior.

The findings clearly demonstrate that integrating mobile learning with structured eco-facilitator coaching significantly enhances ecological engagement among marginalized urban youth, across cognitive, emotional, behavioral, and continuity dimensions. The notably higher gain scores in the experimental group underscore that while digital learning tools offer foundational knowledge, meaningful behavior change requires human guidance through reflective facilitation and reinforced actions. This outcome aligns with recent Education for Sustainable Development (ESD) literature, which emphasizes the effectiveness of multi-component interventions in transforming environmental awareness into sustained ecological habits (Du et al., 2025; Santiago & Rivera, 2023). Accordingly, the intervention addresses the persistent knowledge–action gap often observed in mobile environmental education programs.

The JawaraEco application's interactive features including learning modules, reflective quizzes, progress dashboards, and real-world sustainability challenges proved effective in facilitating the shift from "learning about sustainability" to "practicing sustainability." The substantial cognitive and behavioral gains among users suggest that multimodal elements such as missions, habit-tracking, and evidence-based reporting successfully activated mechanisms identified in digital behavior change models (Rokka, 2025; Hayes et al., 2023). These components not only enhanced users' sense of agency and accountability but also helped contextualize their learning experiences within daily life, reinforcing prior research that well-designed mobile platforms can catalyze ecological action through goal-setting, timely feedback, and experiential learning pathways.

The significantly stronger outcomes observed in the experimental group also highlight the indispensable role of eco-facilitators. Participants with higher levels of facilitator interaction exhibited greater behavioral consistency, supporting findings that mentorship amplifies digital learning impacts by fostering reflection, emotional reinforcement, and self-efficacy (Ngugi et al., 2023; Silva & Duarte, 2020). In this study, coaching served as a relational scaffold that mitigated the common drop-off rates associated with digital-only interventions and facilitated the internalization of environmental values. These results affirm the critical contribution of human interaction in transforming intention into sustained behavior.

JawaraEco's fusion of digital content, real-world tasks, and ongoing behavioral monitoring reflects a broader shift toward integrated ESD models that embed feedback loops into the behavior change process. The uniform improvements across all EAEI dimensions are consistent with research showing that cognitive, emotional, and behavioral engagement is maximized when reinforced through structured, continuous tracking and support (Xiong et al., 2024; Du et al., 2025). The large effect sizes observed in this study further suggest that the alignment of usage metrics (e.g., sessions, modules completed, and action submissions) with facilitator-led reflection fosters a coherent learning ecosystem that supports long-term behavioral consistency.

Importantly, the intervention's success in low-income urban neighborhoods illustrates its relevance and applicability within community-based environmental education, especially in dense settlement clusters such as Rukun Warga (RW). The consistent behavioral gains across Jakarta's regions suggest that JawaraEco is scalable for broader implementation across school-based programs, municipal youth initiatives, and NGO-led campaigns. These findings reinforce calls for environmental education models that blend digital tools with localized mentoring to overcome structural constraints faced by marginalized populations (Khatib & Yeo, 2022). The JawaraEco framework thus offers a viable pathway to strengthen ecological literacy and household sustainability practices in urban contexts.

From a theoretical perspective, the study contributes to expanding environmental behavior change models by showing that mobile learning, guided reflection, and evidence-based behavioral monitoring are most effective when integrated into a cohesive system. This supports and extends constructs from Self-Determination Theory, illustrating how competence, autonomy, and relatedness can be activated through digital prompts, personalized feedback, and mentor validation (Deci & Ryan, 1985; Du et al., 2025). The significant improvements across all engagement dimensions further support the growing consensus that hybrid designs combining digital and human elements are essential for bridging the knowledge–action gap in environmental education (Hayes et al., 2023).

Practically, the study provides robust evidence for the effectiveness of digital sustainability programs that pair mobile learning with structured facilitator involvement. The JawaraEco model featuring interactive modules, mission tracking, and mentor feedback demonstrates strong potential for adoption by governments, NGOs, schools, and community centers. Similar to success stories from Brazil and the Philippines (Santiago & Rivera, 2023; Silva & Duarte, 2020), this approach offers a low-cost, high-engagement solution that supports youth-led ecological actions aligned with SDG 11 (sustainable cities) and SDG 13 (climate action).

While all dimensions of ecological engagement improved significantly, the minimal difference in cognitive pre-test scores between groups suggests that marginalized youth may already possess baseline environmental awareness. However, without continued support, this awareness often fails to evolve into action (Radjabov et al., 2025). Regional variations in engagement were also statistically insignificant, indicating that the intervention's effects were consistent across different urban contexts. This homogeneity may reflect the universal accessibility of mobile learning when accompanied by targeted facilitation (Ngugi et al., 2023), highlighting the adaptability of the intervention across diverse low-resource settings.

Nonetheless, the study has several limitations. First, the 10-week duration limits conclusions about long-term habit formation, as behavior sustainability typically requires extended observation beyond 90 days (Du et al., 2025). Second, although efforts were made to verify actions through photo submissions, self-reported data still carry a risk of bias. Third, the findings are geographically constrained to Jakarta's urban poor, limiting their generalizability to rural or peri-urban contexts. Future research should adopt longitudinal and mixed-methods approaches, incorporate ecological footprint measures, and explore regionally diverse populations. Integrating adaptive AI-based mentoring and community-level reinforcement mechanisms may further enhance long-term impact and ecological habit consolidation.

D. CONCLUSION

This study investigated the impact of a hybrid intervention merging a mobile learning application with eco-facilitator coaching on enhancing ecological engagement among marginalized urban youth. Statistical analyses revealed a consistent pattern: participants exposed to both digital tools and structured facilitation demonstrated significantly greater gains in cognitive understanding, emotional connection to environmental issues, behavioral application, and habit continuity than those in the control group. These results affirm that mobile learning, while valuable, is substantially more effective when complemented by human interaction, guided reflection, and real-world task reinforcement.

From a theoretical standpoint, the study reinforces and expands contemporary models of environmental behavior change by highlighting the importance of integrated ecosystems of learning, action, and social reinforcement. The findings illustrate how ecological engagement is most effectively cultivated through a synergistic combination of technological, pedagogical, and relational supports. Practically, the JawaraEco model offers a scalable and replicable framework for use by community-based organizations, schools, NGOs, and local governments aiming to promote sustainable behaviors in low-resource urban settings. The intervention demonstrates how digital platforms can be leveraged to convert environmental knowledge into consistent, meaningful ecological practices.

Despite its strengths, the study acknowledges several limitations. The relatively short duration of the intervention limits the ability to assess long-term habit sustainability. In addition, the partial reliance on self-reported behavioral data, even when supplemented with photographic evidence, may introduce bias. Furthermore, the geographic scope was limited to specific marginalized communities in Jakarta, which may constrain generalizability. Future research should incorporate extended longitudinal designs, diversify participant demographics, employ more objective behavioral measures, and utilize mixed-method approaches to explore motivational and sociocultural dynamics in greater depth.

In sum, this study provides strong empirical support for the efficacy of combining mobile learning technologies with structured facilitation to foster lasting ecological engagement among urban youth. It contributes both theoretical insight and practical direction for the advancement of environmental education in complex, low-resource urban environments.

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