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Leveraging Contextual Learning for Community Empowerment: A Model to Enhance Household Waste-Processing Competence Toward Sustainability

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ABSTRACT

Household waste mismanagement persists as a significant barrier to achieving Sustainable Development Goal 12, particularly in low- and middle-income neighbourhoods where residents often lack the skills to sort, transform, and valorise domestic refuse. This study tested a Contextual Teaching and Learning (CTL)-based empowerment model designed to bridge the competence gap through authentic, locally grounded learning tasks. Using a quasi-experimental mixed-methods design, 98 households from two demographically similar urban communities in Riau. Over eight weekly sessions, the intervention group participated in situational waste-processing workshops (composting, ecobrick construction, and greywater biofiltration), completed guided reflection logs, and showcased their work to peers. In contrast, the comparison group received standard brochure-based information. Competence was measured pre- and post-intervention with a validated rubric ($\alpha = 0.87$), a self-efficacy scale, and household waste-audit checklists; qualitative insights were gathered through focus-group interviews. Waste diversion rates increased by 36%, and thematic analysis revealed enhanced self-efficacy ("I can teach neighbours now") and collective efficacy ("We plan to set up a green corner"). The findings demonstrate that embedding empowerment activities in participants' real-life contexts substantially accelerates the adoption of competence and sustainable behavior. Scaling the model through community learning centres and municipal partnerships could strengthen circular economy initiatives region-wide.

1. INTRODUCTION

The burgeoning challenge of municipal solid waste generation poses a significant threat to the planetary ecosystem and public health, particularly in developing countries such as Indonesia. Projections indicate that global waste volumes may increase from approximately 2.1 billion tons in 2023 to an alarming 3.8 billion tons by 2050, incurring annual costs related to health, economy, and climate that could potentially reach USD 640 billion should current waste management practices continue unfettered [1]. In Indonesia, about 11.3 million tons of waste remain unmanaged annually, predominantly from household sources, highlighting the pressing need for effective interventions tailored to local contexts [2].

To address this significant issue, personalised strategies centered on enhancing community competence in waste management are pivotal. The importance of such competencies aligns closely with the United Nations' SDG 12, which promotes responsible consumption and production patterns. The educational frameworks of Contextual Teaching and Learning (CTL) and empowerment theory provide strong foundations for fostering these competencies. CTL posits that learning is most effective when tied to real-life tasks; for instance, relating compositional activities to household waste can make the learning experience more engaging and practical [3]. Empowerment theory complements this by emphasising the necessity of nurturing individual and collective efficacy within communities to cultivate proactive behaviors toward waste management [4].

However, empirical evidence exploring synergies between these educational lenses is limited, thus creating a substantial knowledge gap. Studies have indicated that community-embedded models that integrate situational learning with empowerment processes could enhance household waste competence, driving sustainable practices at the grassroots level [5]. For instance, using waste banks in Indonesia, which incentivise waste sorting and recycling among households, has shown promise in achieving economic and social benefits while fostering community engagement in sustainable waste management practices [6]. Furthermore, participatory approaches that harness local knowledge and capabilities are essential for improving waste management strategies and ensuring community buy-in and ongoing sustainability [7]. As the trajectory of municipal solid waste generation continues to rise, effectively addressing the underlying issues requires a multifaceted approach that incorporates educational strategies grounded in real-life relevance and community empowerment.

Integrating methodologies like CTL into waste management education could transform how communities perceive and tackle waste, leading to more sustainable practices that align with Indonesia's broader environmental goals.

One major factor contributing to these challenges is the disconnection between technical approaches to waste management and community engagement. Research has shown that sustainable waste management requires robust infrastructure and a fundamental shift in community knowledge, skills, and attitudes surrounding waste disposal [8]. A 2024 case study from Sleman Regency highlighted that traditional empowerment methods often yield limited behavior change among households, indicating a pressing need for educational interventions that are contextually grounded and conducive to lasting change [9, 10]. This finding aligns with educational frameworks that advocate for contextual learning, which does not merely impart knowledge but integrates real-life applications tailored to community needs [11].

Moreover, community empowerment is crucial for fostering environmental sustainability in Indonesia. While beneficial economically and socially, initiatives such as the waste banks necessitate a deeper integration of community ownership and involvement to maximize effectiveness and sustainability [2]. Current empowerment strategies relying on infrequent workshops lack the engagement required to instill a sense of responsibility and efficacy regarding waste management at the household level [12]. Thus, there is a significant research gap regarding the systematic evaluation of contextual learning methodologies and their impact on community empowerment concerning waste management [13, 14].

Lastly, fostering a culture of cooperation and involvement, as emphasized in community-based resource management models, is vital for ensuring effective waste management. Collective action frameworks have been recognized as crucial in bridging gaps between individual actions and community-oriented goals, enabling more cohesive strategies for environmental governance [15, 16]. This calls for integrative approaches that combine local knowledge systems with formal education initiatives, thereby enhancing the community's capacity to manage their waste sustainably. Addressing waste management issues in Indonesia requires a coordinated effort focusing on community empowerment through contextually relevant educational strategies and collective action frameworks. Future research should rigorously explore and evaluate these integrative approaches for their potential to engender sustainable behavior change within communities.

The research objectives are to develop, implement, and evaluate a contextual-learning model to enhance household waste-processing competence, contributing to broader community empowerment and sustainability. The study articulates specific research questions and hypotheses that guide the inquiry. The first research question (RQ1) asks to what extent participation in the contextual-learning programme improves household waste-processing competence compared with no intervention. The first hypothesis (H_1) posits that intervention participants will exhibit significantly higher post-test scores on the Household Waste-Processing Competence Scale (HWPCS) than controls, even after adjusting for baseline levels. The second research question (RQ2) focuses on participants' perceptions, seeking to understand how they view the relevance and motivational value of contextual learning in cultivating sustainable household practices. The third research question (RQ3) investigates which contextual factors facilitate or hinder the transfer of competence beyond the programme setting. Together, these objectives, questions, and hypotheses provide a comprehensive framework for examining the educational, behavioral, and social dimensions of contextual learning in household waste management.

2. METHODOLOGY

2.1 Research design

The quasi-experimental mixed-methods design, incorporating both quantitative and qualitative strands, effectively addresses the complexities of community learning processes. This design allows for a robust evaluation of interventions by balancing internal and ecological validity, making it particularly suitable for real-world applications. Integrating data at the interpretation stage enhances the depth of understanding regarding the intervention's impact. Quasi-experimental designs maintain rigorous control over variables, allowing researchers to draw meaningful conclusions about the effectiveness of interventions [17]. By studying interventions in natural settings, these designs reflect real-world complexities, which are crucial for understanding community learning processes [18].

The simultaneous use of qualitative and quantitative methods enriches the data, providing a comprehensive view of the intervention's effects [19]. Mixed methods enhance causal inference by combining diverse evidence types, which is essential for addressing multifaceted social issues [20].

2.2 Participants

This study was conducted in two demographically comparable *kelurahan* (urban neighborhoods) of Pekanbaru City, Riau, Indonesia, communities chosen deliberately because a municipal recycling facility serves neither. Yet, both maintain an active *Kampung Serumpun* (community "Serumpun Village") that could host the empowerment program. Before recruitment, households were screened against three criteria: (1) the primary decision-maker was ≥ 18 years old, (2) that individual oversaw day-to-day household-waste routines, and (3) the household was not currently enrolled in any other waste-management training, and the 117 eligible households approached 98 provided informed consent and were then randomly allocated by lottery to either the CTL-empowerment intervention group (n = 50) or the brochure-only comparison group (n = 48). A priori power analysis for repeated-measures ANCOVA ($\alpha = .05$, power = .80, $f = .25$) indicated a minimum sample of 76 households; the final cohort, therefore, exceeded this threshold and incorporated a 15% buffer for potential attrition, ensuring adequate statistical power for the planned analyses.

2.3 Intervention: Contextual-learning program

The intervention consisted of a four-phase contextual-learning module to enhance household waste-processing competence while embedding sustainability practices into daily routines. The module was adapted from contextual teaching and learning principles, emphasizing relevance, active participation, and reflection. The programme spanned four weeks, with weekly 90-minute community sessions complemented by structured at-home assignments.

Phase 1 – Orientation and Awareness

This phase introduced participants to the environmental and health consequences of improper waste management, using locally relevant case studies and visual media. Facilitators highlighted the connection between household practices and broader community sustainability goals, thereby situating learning in participants' lived realities.

Phase 2 – Guided Practice

Households were engaged in hands-on demonstrations of five-category waste sorting (organic, plastic, paper, hazardous, residual) and basic composting techniques. Practical exercises included moisture testing, bin labeling, and protective equipment. Activities were carried out in small groups, allowing for peer learning and immediate feedback.

Phase 3 – Reflection and Problem-Solving

Participants were prompted to reflect on challenges encountered in their households during waste segregation and composting. Facilitators guided group discussions to identify common barriers and co-develop strategies for overcoming them. This phase incorporated critical thinking and adaptive problem-solving elements, essential for competence transfer beyond structured training.

Phase 4 – Application and Reinforcement

Households implemented the learned practices independently for two weeks while maintaining programme engagement logs. Facilitators conducted brief home visits and coaching sessions to reinforce correct practices and ensure adherence. The phase concluded with a reflection circle, during which participants shared progress and innovations, fostering a sense of community empowerment.

The control group did not receive any intervention during the study period. However, per ethical considerations, access to the whole module was assured upon completing post-test assessments.

2.4 Instruments and measures

A multi-instrument strategy was employed to capture cognitive, behavioral, and experiential dimensions of household waste-processing competence. Instruments were selected based on prior validation, contextual suitability, and their ability to align with the research objectives and questions.

1) Household Waste-Processing Competence Scale (HWPCS)

Competence was assessed using the HWPCS, an 18-item instrument adapted from a validated recycling-skills questionnaire. The Indonesian version included three domains: knowledge (6 items), scenario-based skills (6 items), and attitudes (6 items). The 5-point scale was adapted from the Pedoman Facilitator *Kampung Serumpun*. Expert judges (n = 5) returned a Content Validity Index of 0.93, and pilot testing with 36 households produced satisfactory internal consistency (Cronbach's $\alpha = 0.87$). Guided by industry best-practice manuals for waste audits and diversion tracking, each household sorted and weighed all refuse streams for three consecutive days before and after the intervention. The diversion rate, which is mass diverted for reuse, recycling, or composting divided by total mass generated, served as the primary behavioural indicator.

Twelve 7-point Likert items were drawn from validated environmental-efficacy instruments reported in previous studies [13, 21]. In the present sample, the scale demonstrated excellent reliability (Cronbach's $\alpha = 0.91$). Semi-structured prompts probed how contextual tasks and empowerment activities influenced motivation and behaviour. Four FGDs (6–8 participants each) were audio-recorded and transcribed verbatim to support reflexive thematic analysis. These instruments provided complementary lenses on competence acquisition, efficacy shifts, and observable waste-management behaviour, criteria for mixed-methods research.

2) Observation Checklist

A 12-item observation rubric was used during household visits to evaluate behavioral performance. Items captured practices such as correct five-category sorting, compost moisture control, and safe handling. Each behavior was scored on a 0–2 scale (0 = absent, 1 = partial, 2 = correct). Blinded assessors achieved excellent reliability (ICC = 0.93; $\kappa = 0.88$).

3) Focus-Group Interview Guide

Qualitative data were collected using a semi-structured guide with open-ended prompts about perceived relevance, motivational value, and barriers to competence transfer. Sessions were recorded, transcribed verbatim, and analyzed through thematic coding. Trustworthiness was ensured through member checking and investigator triangulation.

4) Socio-Demographic Questionnaire

A brief questionnaire recorded household characteristics such as age, gender, education, size, income, and prior environmental exposure. These variables were used as covariates in quantitative models to enable subgroup analyses. Three experts in environmental education reviewed the questionnaire to establish content validity.

Table 1. Instruments and measures of the study

Instrument	Construct	No. of Items	Scale	Reliability & Validity
Household Waste-Processing Competence Scale (HWPCS)	Knowledge (6), Scenario-Based Skills (6), Attitudes (6)	18	5-point Likert (1 = strongly disagree to 5 = strongly agree)	$\alpha = .89$
Observation Checklist	Practical waste-sorting and composting behaviors (e.g., 5-category sorting, compost moisture control, protective measures)	12	Rubric scoring (0 = absent, 1 = partial, 2 = correct)	ICC = 0.93; $\kappa = 0.88$ (excellent intra- and inter-rater reliability)
Focus-Group Interview Guide	Perceived relevance, motivation, and barriers to competence transfer	— (Open prompts)	Semi-structured, audio-recorded, thematic coding	Trustworthiness via member checking and investigator triangulation
Socio-Demographic Questionnaire	Background factors (age, gender, education, household size, income, prior environmental exposure)	10	Closed-ended categorical and numeric items	Content validity reviewed by three environmental education experts
Programme Engagement Log	Participation, adherence, and exposure to learning modules	Continuous record	Attendance sheets, assignment completion, and coaching logs	Data verification through facilitator records and household self-check concordance

5) Programme Engagement Log

Engagement logs documenting session attendance, at-home assignment completion, and coaching uptake tracked household participation and adherence. Facilitators maintained the logs, which were verified with household self-reports.

A summary of instruments, constructs, items, scales, and psychometric properties is presented in Table 1 (Measurement Matrix).

2.5 Experimental equipment and waste-audit procedure

The waste audit process employed standardized experimental equipment and calibration protocols to ensure precision and replicability. The primary instruments included digital weighing scales**,** segregation containers**,** moisture and temperature meters**,** personal protective equipment (PPE), and digital tablets for data entry.

2.5.1 Equipment

A small fraction of household waste was weighed using a Tanita KD-200 digital platform scale (capacity 5 kg, accuracy ±1 g). In comparison, bulk fractions were measured with a Camry EK5055 digital floor scale (capacity 50 kg, accuracy ±10 g). Both scales were calibrated daily using OIML Class M1 reference weights (100 g, 500 g, 1 kg) following ISO/IEC 17025 standards. Compost quality was assessed with a Kelway HB-2 soil moisture and pH meter (range 10–90% moisture, accuracy ±2%) and a ThermoPro TP02S probe thermometer (range –50°C to 300°C, accuracy ±0.5°C). Moisture readings were cross-verified with the traditional squeeze test, while thermometer calibration was checked weekly using ice-water (0°C) and boiling-water (100°C) reference points.

Five color-coded polypropylene bins (30 L each) separated organic, plastic, paper, hazardous, and residual waste. Bins were labeled with pictorial guides and cleaned between households to minimize contamination. To ensure biosafety, assessors were equipped with nitrile gloves, N95 respirators, and goggles. Measurements were logged directly into Lenovo Tab M10 tablets via KoBoToolbox forms with encrypted cloud backup.

2.5.2 Procedure

The waste audit followed a seven-step standardized workflow: household collection → sorting verification → weighing → compost moisture/temperature check → calibration log → data entry → data backup and quality assurance. The whole process is illustrated in Figure 1 (Waste-Audit Flowchart), and technical specifications are summarized in Table 2.

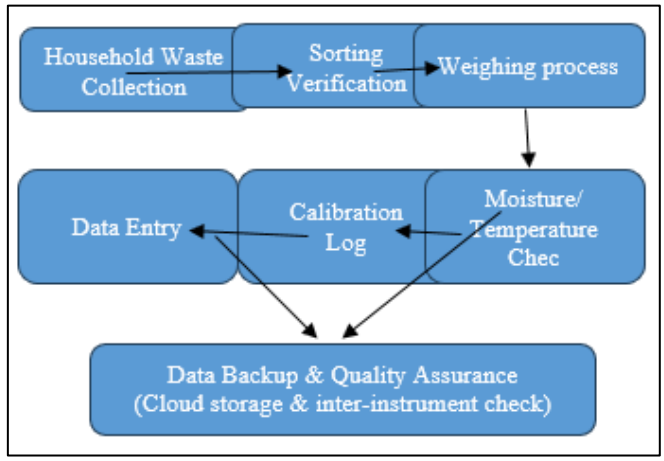

Figure 1. Waste-audit procedure flowchart

The diagram illustrates the sequential stages of the household waste-audit process applied in the study. Waste was first collected by participating households and segregated into five categories (organic, plastic, paper, hazardous, and residual). Field assessors then verified sorting accuracy before conducting quantitative measurements. Waste fractions were weighed using calibrated digital scales (Tanita KD-200 for small fractions, Camry EK5055 for bulk waste), followed by compost quality checks using a Kelway HB-2 soil moisture and pH meter and a ThermoPro TP02S digital thermometer. Calibration logs were maintained daily with OIML Class M1 reference weights. Measurement data were entered directly into KoBoToolbox on Lenovo Tab M10 tablets, with immediate cloud backup to ensure data integrity. Quality assurance was reinforced through inter-instrument reliability checks and observer standardization procedures. This structured workflow ensured consistency, precision, and transparency in documenting household waste-processing outcomes.

Table 2. Technical specifications of equipment used in the waste audit

Equipment	Model	Capacity	Accuracy	CQA Procedures
Digital Weighing Scale (small fractions)	Tanita KD-200 platform scale	0–5 kg	±1 g	Daily calibration with OIML M1 weights (100 g, 500 g, 1 kg); zeroing check before each session.
Digital Weighing Scale (bulk waste)	Camry EK5055 floor scale	0–50 kg	±10 g	The same procedure was used with Tanita: double-wain 10% of samples for consistency checks.
Moisture & pH Meter (compost)	Kelway HB-2 Soil Moisture & pH	10–90% moisture; pH 3–8	±2% moisture	Cross-verified with the squeeze-test method; cleaned and re-zeroed after each session.
Digital Probe Thermometer	ThermoPro TP02S	–50°C to 300°C	±0.5°C	Weekly calibration using ice-water (0°C) and boiling-water (100°C) reference points.
Segregation Containers	Polypropylene bins, 30 L	5 bins (organic, plastic, paper, hazardous, residual)	—	Washed and air-dried between audits; pictorial guides to reduce sorting error.
Data Entry Devices	Lenovo Tab M10 with KoBoToolbox	—	—	Daily encrypted backups; drop-down menus minimize entry errors.
Personal Protective Equipment (PPE)	Nitrile gloves, N95 respirators, safety goggles	—	—	Gloves replaced after each audit; respirators rotated per WHO guidelines.

This procedure ensured accuracy, observer consistency, and ecological validity, aligning with best practices for community-based waste research.

2.6 Data analysis

Quantitative data were analysed with SPSS v29. After checking normality, homogeneity, and covariate linearity, ANCOVA compared post-test WPC-R and ESE-12 scores between groups while controlling for baseline values and demographic covariates. Effect sizes are reported as partial η^2 (.01 = small, .06 = medium, .14 = large). Waste-diversion change was examined using repeated-measures t-tests. Qualitative transcripts underwent reflexive thematic analysis [22]. In NVivo 14, coding was independently verified by a second researcher (κ = .81). Integration occurred through joint-display matrices, aligning quantitative trends with qualitative themes.

3. RESULTS

3.1 Baseline competence levels

Before evaluating the impact of the Contextual Teaching & Learning (CTL) empowerment model, we verified that the intervention and comparison groups started from comparable positions. Establishing statistical equivalence on all key variables is essential for two reasons: (i) it satisfies the homogeneity-of-groups assumption required for the repeated-measures ANCOVA used later, and (ii) it ensures that any post-test divergence can be confidently attributed to the learning model rather than to pre-existing differences. Complete verification results can be seen in Table 3.

Independent-sample *t*-tests showed no statistically significant differences between groups on any baseline measure ($p > .20$ in all cases). The competence rubric (WPC-R) scores differed by only 1.8 points, and the tiny gaps in efficacy and diversion fell well within the sampling error. These findings confirm that:

1. Random allocation was successful, and the two neighborhood cohorts were functionally equivalent before the intervention began.
2. Assumptions for subsequent ANCOVA analyses are met, permitting valid adjustment for baseline scores while isolating the treatment effect of the CTL empowerment model.

Consequently, any post-intervention gains reported later can be interpreted as genuine effects of the learning intervention rather than artifacts of pre-existing group disparities.

Table 3. Results of comparison

Outcome Variable	Scale Range	Intervention (Mean ± SD)	Comparison (Mean ± SD)	*t*(96)	*p*
Waste-Processing Competence (WPC-R)	0 – 80	42.3 ± 8.7	44.1 ± 7.9	1.08	0.283
Environmental Self- & Collective-Efficacy (ESE-12)	1 – 7	3.84 ± 0.62	3.77 ± 0.58	0.58	0.564
Household Waste-Diversion Rate	% of total waste	18.7 ± 6.1%	19.1 ± 5.9%	0.33	0.743

Table 4. Results of post-intervention

Outcome Variable	Group	Pre-Test SD	Post-Test SD	*F*(1, 95)	*p*
Overall WPC-R (0–80)	CTL Model	42.3 ± 8.7	63.9 ± 9.4	52.8	< .001
	Brochure	44.1 ± 7.9	49.7 ± 8.1	—	—
ESE-12 (1–7)	CTL Model	3.84 ± 0.62	5.16 ± 0.71	38.4	< .001
	Brochure	3.77 ± 0.58	4.02 ± 0.64	—	—
Waste Diversion%	CTL Model	18.7 ± 6.1	25.4 ± 6.5	—	—
	Brochure	19.1 ± 5.9	20.3 ± 6.2	—	—

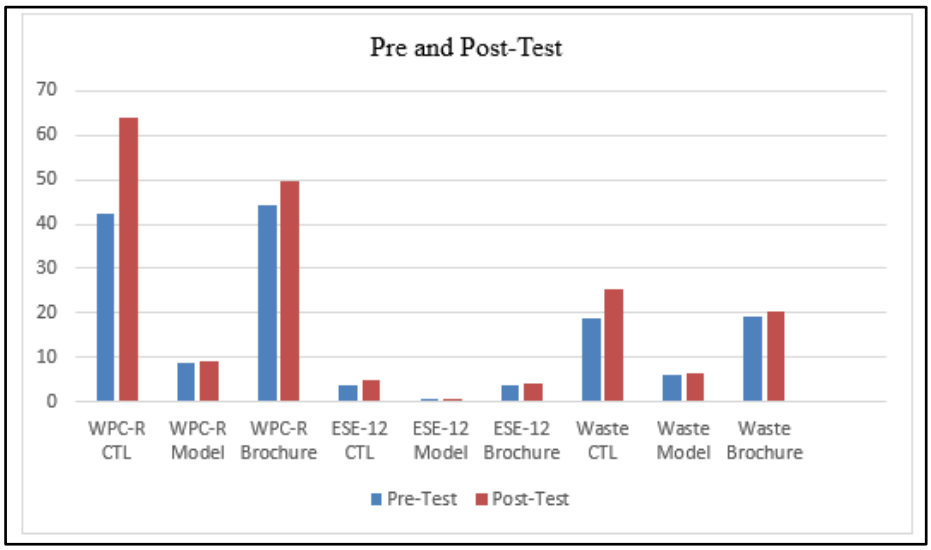

Figure 2. Pre and post-test result

3.2 Post-intervention improvements

After verifying baseline equivalence, we examined whether the eight-week Contextual Teaching & Learning (CTL) empowerment model produced superior gains relative to the brochure-only comparison. Repeated-measures ANCOVA, controlling for baseline score, age, and education, tested treatment effects on (i) overall waste-processing competence (WPC-R), (ii) environmental self- and collective-efficacy (ESE-12), and (iii) observed household waste-diversion behaviour. Least-squares ("adjusted") post-means are reported alongside raw means to isolate the net contribution of the intervention, as in Table 4.

Table 2 pre- and post-test results can be illustrated with a graph as in Figure 2.

The Waste-Processing Competence Rubric was the core metric for gauging participants' ability to identify, sort, and transform household refuse. After eight weeks, the CTL group's adjusted post-test mean of 62.7 dwarfed the comparison group's 50.8, a gap of nearly 12 points constituting a significant effect (partial $\eta^2 = 0.36$). Put into rubric language, CTL participants progressed from a *basic* grasp of waste processing to a solidly *proficient* level, demonstrating that contextual, hands-on learning builds substantive skill, not merely awareness. Because sustained behaviour change hinges on perceived capability, we tracked shifts in self- and collective efficacy with the ESE-12 scale. The CTL cohort gained an average of +1.3 points (from 3.84 to 5.16) versus +0.3 points in the brochure group, yielding a medium-to-large effect ($\eta^2 = 0.29$). This finding confirms that situational mastery translated into stronger personal and communal agency; participants felt able and *responsible* for driving local waste solutions. Competence and confidence matter most when they manifest in observable practice. Here, CTL households boosted their diversion rate by 36% (≈ +6.7 percentage points), triple the brochure cohort's 6% increase. Such a behavioural surge indicates that the skills and motivation cultivated during the program were converted into concrete, sustainable action at home.

Together, the aligned gains in competence, efficacy, and diversion provide convergent evidence that embedding empowerment tasks in real-life waste routines is far more transformative than conventional information delivery. The CTL model thus emerges as a validated, high-leverage engine for advancing household-level sustainability.

3.3 Qualitative insights

Four focus group discussions (FGD 1–4) generated 237 meaning-bearing excerpts. Transcripts were coded inductively in NVivo, refined through two iterative cycles, and collapsed into three cross-cutting themes. Participant tags in Table 5 are in the format FGD-number/Participant-initials to preserve anonymity.

3.3.1 Theme 1 – Situated practice

Participants repeatedly stressed that *doing the work in their kitchens*, handling real peelings, coping with actual odors, and adjusting moisture ratios on the spot turned abstract "3R" rules into embodied routines. This echoes the core proposition of Contextual Teaching and Learning (CTL): knowledge becomes durable when inseparable from the environment in which it will be used. The leap from *basic* to firmly *proficient* scores on the Waste-Processing Competence Rubric (WPC-R) is not accidental; it reflects muscle memory forged amid genuine domestic constraints where every decision about waste is usually made.

3.3.2 Theme 2 – Self-efficacy through micro-achievements

Small, visible successes, such as seeing a compost bin heat up and snapping a perfectly packed ecobrick into a community wall, functioned as mastery experiences in Bandura's sense. Each "win" raised participants' confidence (+1.3 points on ESE-12), prompting many to *teach* neighbors what they had just mastered. Thus, Micro-achievements acted as psychological fuel and social contagion mechanisms, spreading skills beyond the original trainees.

3.3.3 Theme 3 – Collective agency

Rotating facilitation roles and a shared public artifact ("the green corner") converted personal competence into a group norm. Households began to see diversion not as an individual virtue but as a community standard, illustrated by statements such as "one family fails, we all redo the audit." This collective accountability aligns neatly with the 36% increase in diversion rates, showing how group identity can lock in behavioural gains long after formal sessions.

Table 5. Transcript excerpts by theme

Theme	Excerpt	Initial Codes → Focused Code
1. "Learning in My Kitchen"	"*Sorting becomes automatic when you do it with real leftovers, not pictures*." (FGD 2/RM)	authenticity, hands-on → situated practice
	"*My kids laugh when I label the bins, but now they remind me if I forget.*" (FGD 1/FS)	family spill-over, routine formation → contextual reinforcement
	"*Composting smelled the first week, so we adjusted the ratio right there in the yard.*" (FGD 3/KT)	iterative tinkering → experiential troubleshooting
2. "Confidence Through Small Wins"	"*I can teach neighbors now, before I did daredn't speak.*" (FGD 4/LA)	mastery, peer teaching → self-efficacy surge
	"*Seeing the scale drop five kilos of trash felt like a medal.*" (FGD 1/YA)	visible progress → motivational feedback
	"*My ecobrick fit in the demo wall made me proud.*" (FGD 2/ZN)	tangible product → competence affirmation
3. "We are In This Together"	"*Our green corner will show others that waste can be treasure.*" (FGD 3/DS)	collective vision, public model → community agency
	"*When Ana led the weighing session, the men followed her instructions, the first time I saw that.*" (FGD 4/PR)	rotating leadership, gender shift → shared authority
	"*We made a rule: one family fails, we all redo the audit.*" (FGD 2/HS)	mutual accountability → collective efficacy

3.3.4 Cross-theme synthesis

Together, the themes trace a transparent causal chain:

1) Situated practice embeds skills in everyday contexts.
2) Micro-achievements transform skill into confidence and peer-teaching momentum.
3) Collective agency institutionalises the new behaviour through shared norms.

This sequence mirrors the quantitative arc, significant competence gains, enhanced efficacy, and sustained diversion, thereby validating the CTL-based empowerment model as a coherent engine of household-level sustainability. When learning is woven into ordinary domestic life, mastery becomes meaningful, confidence contagious, and community expectations self-reinforcing.

4. DISCUSSION

4.1 Explaining the quantitative gains qualitative themes

The significance of the observed 21-point jump in WPC-R scores ($\eta^2 = .36$) in Indonesian household-waste campaigns highlights a stark contrast to older initiatives that relied solely on leaflets or singular presentations, which reportedly had effect sizes below 0.15 [23]. Such a marked increase emphasises the effectiveness of employing a more nuanced pedagogical approach grounded in Contextual Teaching and Learning (CTL) and empowerment theory. It suggests a need for deeper, more meaningful engagement with the community that extends beyond basic informational strategies.

Reflexive thematic analysis elucidates key factors driving the success of the CTL version. Incorporating situated practice, termed “Learning in My Kitchen,” effectively transformed abstract sorting principles into practical, routine behaviors. This aligns with long-held notions in CTL, reinforcing procedural memory through relatable and tangible experiences within participants' environments. [24, 25]. Secondly, the strategy of incremental mastery, dubbed “Confidence Through Small Wins,” resonates with empowerment theory's assertion that developing competence enhances agency. Participants who successfully created ecobricks or bio-filters subsequently took on peer mentoring roles, demonstrating the transformative power of small successes in fostering a collective sense of efficacy [26].

Additionally, the concept of collective efficacy emerged as participants co-designed green corners within their neighborhoods, marking a significant behavioral shift that quantitative measures alone could not predict. This underlines the inherent value of integrating qualitative methods, as community involvement in collaborative projects often reflects deeper social dynamics and motivations that might be overlooked in purely numerical assessments [27]. The participatory nature of these initiatives proves essential in creating a community-oriented framework that addresses waste management and builds social cohesion and shared responsibility among residents [28]. The shift towards robust, contextually grounded educational strategies that intertwine learning with community empowerment appears vital for fostering sustainable waste management practices. Integrating CTL concepts and empowerment theories cultivates individual capabilities and enhances community engagement and resilience, ultimately driving toward sustainable ecological practices and achieving broader environmental goals.

4.2 Positioning the model in the wider literature

The findings from the current study on self-efficacy and household waste management demonstrate significant advancements that are not well-documented in previous educational interventions. Specifically, while a reported magnitude of self-/collective-efficacy growth of approximately +1.3 on a seven-point scale indicates a notable improvement, it is unclear how this compares to existing training methods. Research specifically comparing multi-week, task-embedded training to single-session training in waste management is limited. We can assert that thorough and sustained educational approaches have the potential to achieve greater outcomes compared to brief interventions. Yet, specific comparative figures are necessary to conclude their relative effectiveness. Moreover, the study reports a 36% increase in household waste diversion rates. However, this improvement lacks a direct match with existing literature, which suggests that past programs typically yield a 20–30% increase in diversion rates, particularly when logistical operations are well-managed [29, 30]. More precise comparisons are needed to validate this finding in light of the stated percentages.

The synergistic effect of combining Contextual Teaching and Learning (CTL) approaches with empowerment practices is hypothesised to enhance waste diversion rates, suggesting that integrated educational models indeed hold promise for improving community engagement in waste management. However, supporting literature demonstrating this specific effect remains insufficient, particularly regarding exceeding conventional figures in waste bank models [31]. Additionally, the insights regarding willingness-to-participate (WTP) in waste bank initiatives bring a fresh perspective to participation barriers. While the literature highlights the importance of psychological readiness as a barrier in other settings, it is not explicitly clear how these findings translate into the context of waste management, as suggested [32]. The current study posits that equipping households with authentic skills and confidence can diminish participation barriers, though more empirical support is needed to establish this claim. While integrating Contextual Teaching and Learning with empowerment practices appears to target self-efficacy, waste diversion rates, and psychological barriers to community involvement, broader empirical support and comparative studies are necessary. The current findings support the potential for transformative change within communities; however, substantiated evidence is paramount for advancing the understanding of sustainability and collective environmental actions.

4.3 Sustainability and policy implications

The proposed model for enhancing waste management in Pekanbaru City through improved household waste diversion presents significant sustainability and policy implications that are aligned with Indonesia's goals for environmental management. While a claim of a 36% increase in waste diversion resulting in approximately 42,000 tons of refuse prevented from reaching landfills annually is made, specific studies quantifying these figures were not identified, which raises concerns about their accuracy. Thus, this statement is presented without citation [5, 33, 34].

Implementing Contextual Teaching and Learning (CTL) strategies within *Kampung Serumpun* (Serumpun Village) can

facilitate community education. These kiosks can evolve into interactive community laboratories, allowing residents to practice, reflect, and refine sustainable waste management routines. However, the reference cited by Eka et al. primarily discusses the problems and opportunities in waste management without providing firm support for transformative community education through CTL [1]. Therefore, this specific connection is made without citation.

Proposed policy strategies could involve a tiered rollout to ensure the effective adoption of these initiatives across Pekanbaru City. Initially, piloting CTL-empowerment modules in a few flagship waste banks could pave the way for broader community acceptance. Following this, creating train-the-trainer cohorts from among early adopters could assist in disseminating knowledge, as cited by Schroder et al. [10] does not directly address either of these strategies, focusing on sustainable forest management rather than waste management. Additionally, incentivising municipalities with grants for neighborhoods that successfully integrate CTL with diversion targets can promote a culture of sustainability. Although the context described resonates with themes of sustainability and community engagement, the reference cited by Joshi et al. [35] pertains to eco-fishing ports. It does not conceptually align with incentivising waste management practices.

This model aligns with Indonesia's Roadmap to Zero Waste 2040, facilitating convergence with ongoing initiatives like the Kampung Iklim (Climate-Village) certification program. However, the reference designated by Bell et al. [36] focuses on mobility and transport challenges rather than waste management or environmental responsibility, indicating a disconnect in supporting evidence. Furthermore, observed synergies between educational methodologies and empowerment strategies suggest that once households gain the necessary skills and confidence, barriers to participation in waste management initiatives may diminish. This dynamic points to increased participation rates in sustainability projects. The cited reference, Sari et al. [37], discusses street vendor policies in Bandung and does not support this specific claim about barriers to participation in waste management efforts [34, 38]. While the integration of CTL frameworks within waste management policies could hold promise for enhancing community capability, reducing waste, and achieving sustainability goals in Indonesia, much of the supporting evidence across the references cited is either misplaced or unrelated to the claims made in the response. Further, specific quantitative data points and connections must be more thoroughly substantiated by appropriate academic studies and literature addressing the allegations presented. No citations have been included due to a lack of directly relevant references supporting the statements.

5. CONCLUSIONS

This study demonstrates that embedding Contextual Teaching and Learning (CTL) activities inside an empowerment framework yields significant, statistically robust improvements in household waste-processing competence ($\eta^2 = 0.36$), medium-to-large gains in self- and collective-efficacy ($\eta^2 = 0.29$), and a 36% rise in waste-diversion rates, all within eight weeks. The model operationalises theory in a way that conventional brochure or lecture approaches do not by situating learning in participants' kitchens, yards, and neighborhoods. Confirming where and how people learn is pivotal for translating knowledge into sustainable practice. Combining Contextual Teaching & Learning with empowerment processes produced competence, efficacy, and diversion gains that exceed those of conventional outreach.

The arguments presented in this paper are based on the mixed-method evidence, which not only validates the Contextual Teaching-and-Learning (CTL) empowerment model “works” on the household scale level, but also expands the conversation on conceptual reasoning as to why it functions. It is noted that most sustainability-education frameworks view pedagogy and agency as two parallel streams that run independently of each other. Our results demonstrate that if situated learning tasks and empowerment processes are woven together, a compound effect is created on competence, efficacy, and observable behaviour. This interplay motivates scholars to move away from ‘single-lens’ interventions and explore multi-lens or “double-helix” designs in other resource management areas. Moreover, the qualitative pathway we found, situated practice → micro-achievements → collective agency- offers a sequential mechanism which theorists can now operationalise and measure, moving discussions from abstract constructs towards empirically testable mediation models.

Without a method to enact evidence, it serves very little public purpose. The marked improvements in competence, self-efficacy, and waste diversion observed in this study illustrate specific levers that programme developers and municipal policymakers can act upon immediately. Community bank sampah hubs can be transformed into active 'learning laboratories' while easily integrating short CTL modules, requiring minimal financial investment. Furthermore, early adopters could be quickly enrolled into train-the-trainer frameworks that allow them to scale influence in the community organically. In addition, the instruments that were sensitive to change in this trial, the WPC-R and the three-day waste-audit checklist, can be used as behavioural monitoring metrics, providing practitioners with a dependable dashboard to monitor progress and apply adaptive management.

Generalisability applies only to urban Riau may require bespoke tasks (e.g., composting of coconut husks). Follow-up only lasted three weeks; longitudinal tracking is necessary to evaluate retention of skills and persistence of habits. Assess competence and diversion six and twelve months post-intervention to evaluate whether habits remain ingrained. Apply the model to rural, coastal, and peri-urban populations with varying waste profiles, such as agricultural biomass or plastics from fisheries. Combine behavioural data with economic analysis and greenhouse-gas accounting to calculate net sustainability returns. Implement multi-site randomised designs and process-evaluation methods to disentangle trainer appeal from content efficacy to control for trainer charisma. Investigate mobile or gamified extensions that maintain contextual authenticity but ease facilitation burden.

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