

Community education for solid waste management: Knowledge gains in rural area, Pangkep, Indonesia

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ABSTRACT

Although community education is increasingly used to improve solid waste practices, evidence from rural Indonesian villages remains limited, and few programs combine Participatory Rural Appraisal (PRA) with rapid pre-post evaluation; this initiative addresses that gap by testing a community-based educational program in Balocci Baru Village, Pangkep Regency, Indonesia. The program, entitled "Smart Waste Management, Smart Environmental Stewardship," aimed to strengthen community knowledge and understanding of proper, responsible, and sustainable waste management to reduce environmental contamination and downstream public health risks. Using a participatory PRA approach, educational sessions were delivered to 22 participants (community members, health cadres, and local leaders) and evaluated through pre-test and post-test measurements. Visual reinforcement tools (posters and informational boards) were integrated to support comprehension and recall. Post-intervention results indicated a clear improvement in knowledge distribution, with no participants remaining in the low-knowledge category. Statistical testing using the Wilcoxon signed-rank test confirmed a significant increase in knowledge scores ($p < 0.05$). These findings suggest that participatory, visually supported education can be an effective entry point for community-driven waste management in rural settings, with potential adaptation for peri-urban and urban neighborhoods where waste generation and exposure pathways differ but behavior change remains central to environmental health promotion.

ABSTRAK

Meskipun edukasi berbasis komunitas semakin sering digunakan untuk memperbaiki praktik pengelolaan sampah, bukti implementasi di wilayah pedesaan Indonesia masih terbatas, dan hanya sedikit program yang mengintegrasikan Participatory Rural Appraisal (PRA) dengan evaluasi pre-post secara cepat; kegiatan ini mengisi celah tersebut melalui uji program pendidikan berbasis komunitas di Desa Balocci Baru, Kabupaten Pangkep, Indonesia. Program "Smart Waste Management, Smart Environmental Stewardship" bertujuan meningkatkan pengetahuan dan pemahaman masyarakat tentang pengelolaan sampah yang tepat, bertanggung jawab, dan berkelanjutan guna menekan pencemaran lingkungan serta risiko kesehatan masyarakat. Dengan pendekatan partisipatif berbasis PRA, sesi edukasi diberikan kepada 22 peserta (warga, kader kesehatan, dan tokoh masyarakat) dan dievaluasi menggunakan pengukuran pre-test dan post-test. Penguatan materi dilakukan melalui media visual berupa poster dan papan informasi untuk mendukung pemahaman serta retensi pesan kunci. Hasil pascaintervensi menunjukkan perbaikan distribusi pengetahuan, ditandai dengan tidak adanya peserta pada kategori pengetahuan rendah. Uji Wilcoxon juga mengonfirmasi adanya peningkatan skor pengetahuan yang bermakna ($p < 0,05$). Temuan ini menunjukkan bahwa edukasi partisipatif yang didukung media visual efektif sebagai pintu masuk penguatan pengelolaan sampah berbasis masyarakat di pedesaan, serta berpotensi diadaptasi pada wilayah peri-urban dan urban yang memiliki karakteristik timbulan sampah dan jalur pajanan berbeda, namun tetap membutuhkan perubahan perilaku sebagai inti promosi kesehatan lingkungan.

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INTRODUCTION

Global solid waste management (SWM) is increasingly framed through circular economy principles that prioritize waste prevention, resource transformation, recovery, and planning to reduce virgin-material use and associated environmental burdens (Przydatek, 2023; Sánchez et al., 2023). This shift is propelled by accelerating urbanization, intensified consumption, and the imperative to reduce greenhouse gas emissions linked to waste generation and disposal, particularly in developing settings where system capacity often lags behind waste growth (Pereira et al., 2021; Maalouf & Agamuthu, 2023). Yet, waste volumes continue to increase, and substantial proportions remain inadequately managed, indicating persistent implementation gaps between policy aspirations and operational realities (Maalouf & Agamuthu, 2023). The pandemic further amplified these challenges by increasing plastic waste streams and raising collection and hygiene demands, placing additional strain on existing infrastructure and governance arrangements (Vanapalli et al., 2021). Accordingly, contemporary scholarship highlights the need for integrated SWM pathways that combine policy intelligence with operational innovations to accelerate progress toward sustainability targets (Sánchez et al., 2023; Wang et al., 2020).

Improper SWM generates multidimensional environmental contamination—air, soil, and water pollution—and creates conditions conducive to vector proliferation through clogged drainage and unsafe disposal, thereby elevating risks for communicable and non-communicable health outcomes (Omang et al., 2021; Shabani & Jerie, 2023). Documented health impacts include diarrheal disease outbreaks (e.g., cholera), malaria and dengue transmission, and respiratory conditions associated with burning or degraded air quality, with disproportionate impacts in low-resource contexts where collection and treatment capacity are limited (Haruna et al., 2020; Omang et al., 2021; Roustia et al., 2020). Environmental consequences extend to ecosystem degradation and toxic leachate contamination from open dumping and poorly controlled landfills, with emerging concern over microplastic generation and dispersal from waste repositories (Eshete et al., 2024; Saengchut et al., 2024; Salem et al., 2022; Shabani & Jerie, 2023). These interlinked environmental and health pathways underscore SWM as a public health priority requiring context-appropriate interventions and sustained community adoption.

Despite advances in circular economy strategies and technology-enabled SWM, many communities—particularly in low-resource and rural settings—continue to rely on rudimentary disposal practices driven by limited environmental literacy, constrained services, and weak local governance, sustaining avoidable health and ecological risks (Haruna et al., 2020; Omang et al., 2021; Shabani & Jerie, 2023). While smart waste management technologies (e.g., IoT systems, analytics, and digital twins) can improve routing, monitoring, and decision-making, their implementation is frequently concentrated in smart-city contexts and remains constrained by fragmentation, interoperability barriers, and governance capacity (Fei et al., 2024; Schmetz et al., 2020; Sharma et al., 2020; Szpilko et al., 2023). A complementary, scalable solution is therefore needed—one that strengthens community knowledge and responsibility through participatory, locally grounded education and supports behavior change as a foundation for sustainable SWM adoption (Effendi & Murwonugroho, 2025).

Participatory Rural Appraisal (PRA) offers a bottom-up, asset-based framework for environmental education that centers local knowledge, needs, and capacities in co-designing interventions, thereby strengthening relevance, ownership, and feasibility (Cahyaningtyas et al., 2023; Effendi & Murwonugroho, 2025). PRA typically operationalizes participation through iterative planning–action–reflection cycles, stakeholder collaboration, and deliberative methods such as focus group discussions and community mapping, which can improve the uptake of environmental literacy and pro-environmental practices by aligning content with lived experience and local constraints (Cahyaningtyas et al., 2023; Effendi & Murwonugroho, 2025). Across community programs, PRA has also been linked with stronger social accountability and resilience by embedding monitoring and feedback into routine community processes, supporting sustained engagement rather than one-off messaging (Shrivastava et al., 2025; Rahmawati et al., 2025).

In parallel, the smart waste management literature emphasizes the role of digital and data-enabled systems—including sensor-based bins, analytics-driven routing, and digital twins—as enablers of efficiency and environmental impact reduction through real-time monitoring and system optimization (Fei et al., 2024; Rigó et al., 2024; Szpilko et al., 2023). These tools align with circular economy objectives by improving waste auditability, facilitating resource recovery planning, and supporting SDG-oriented outcomes across the waste value chain. However, technology-focused approaches often require governance readiness, standardization, and system interoperability, which can limit adoption and equity in contexts where infrastructure and institutional capacity are uneven (Schmetz et al., 2020; Sharma et al., 2020). Consequently, community-based educational interventions remain essential to translate system goals into household and community practices that reduce leakage and exposure pathways, especially where high-tech deployment is not immediately feasible.

The literature consistently indicates that inadequate SWM drives environmental contamination and disease risks, reinforcing the need for interventions that are both behaviorally effective and locally implementable (Omang et al., 2021; Shabani & Jerie, 2023). PRA-informed education is well-positioned to address these requirements because it strengthens community agency and contextual fit, which are critical determinants of sustained practice adoption in environmental and health-related programs (Cahyaningtyas et al., 2023; Effendi & Murwonugroho, 2025; Shrivastava et al., 2025). Nevertheless, much of the “smart” SWM discourse focuses on urban, technology-intensive infrastructures, while fewer studies emphasize “smart” stewardship as a community capability—namely, informed decision-making, responsible sorting and disposal behaviors, and collective monitoring—particularly in rural settings with limited formal services (Fei et al., 2024; Sharma et al., 2020; Szpilko et al., 2023). This imbalance suggests a practical gap: rural communities need feasible, low-cost pathways that build knowledge and responsibility as foundational inputs to circular and sustainable waste systems, even before advanced technologies become available.

Based on this gap, the present community service program—“Smart Waste Management, Smart Environmental Protection”—was designed as a community-level educational intervention in Balocci Village, Pangkep Regency, to strengthen knowledge and understanding of proper and responsible waste management through a PRA-based participatory approach (Cahyaningtyas et al., 2023; Effendi & Murwonugroho, 2025). The novelty lies in positioning “smart” waste management not only as a technological paradigm but also as an educational and participatory capability that can be cultivated through co-designed learning supported by visual media to reinforce comprehension and retention (Fei et al., 2024; Szpilko et al., 2023). Accordingly, the objective of this program was to evaluate changes in community knowledge before and after the PRA-based educational activity and to demonstrate the feasibility of community-driven waste stewardship as a public health-relevant pathway for reducing environmental risks in rural contexts (Omang et al., 2021; Shabani & Jerie, 2023).

METHODS

This community service program applied a participatory community empowerment approach grounded in Participatory Rural Appraisal (PRA), which emphasizes active community involvement across planning, implementation, and evaluation to ensure that the educational content and proposed actions align with local needs, resources, and capacities (Kurniawan et al., 2025). The program used a one-group pre-test–post-test evaluation design to assess changes in participant knowledge immediately before and after the educational intervention, as this approach is considered effective for measuring the impact of educational activities in relation to predetermined learning objectives (Fakhriyah et al., 2025). The activity was conducted on Tuesday, July 28, 2025, in Balocci Baru Village, Balocci District, Pangkep Regency, Indonesia, following prior coordination with local stakeholders and preparation of educational materials and assessment tools.

The target population comprised adult residents and community stakeholders in Balocci Baru Village who are relevant to household and community waste management practices. A total of 22 participants were recruited through coordination with village authorities and local community networks using purposive convenience sampling to ensure representation from groups with practical influence on daily waste handling and community mobilization, including housewives, health workers,

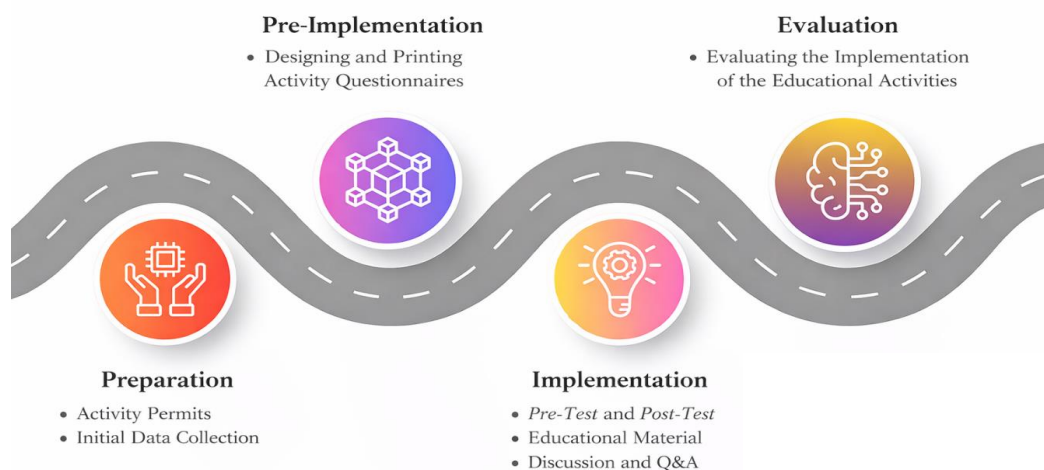
and local community leaders. Participants were included if they were adults residing in or actively serving the village, were willing to participate in the full activity sequence, and provided informed consent. Participants who did not complete either the pre-test or the post-test were designated as ineligible for paired analysis.

The intervention procedures were structured according to PRA-informed planning-action-reflection principles. During the preparation phase, the team identified salient local waste issues through stakeholder communication, then developed and designed educational media, including visual materials such as posters and informational boards to strengthen message clarity and retention. A knowledge measurement instrument was also prepared. On the implementation day, participants completed the pre-test, attended a facilitated educational session focusing on proper, responsible, and sustainable waste management, and then completed the post-test. PRA elements were operationalized through interactive dialogue and participatory discussion, allowing participants to share experiences, identify locally specific barriers, and agree on feasible household- and community-level actions consistent with local environmental conditions and service constraints. Visual media were integrated throughout the session to reinforce core concepts and practical steps that participants could apply in daily life (see Figure 1).

Program outcomes were assessed using a six-item questionnaire designed to measure knowledge related to key waste management concepts. Knowledge was categorized as good when respondents answered at least five questions correctly and poor when fewer than five items were answered correctly. Data analysis combined descriptive and inferential approaches, with participant characteristics and knowledge categories summarized using frequencies and percentages and presented in narrative form supported by tables and/or figures as needed. Pre-test and post-test knowledge scores were compared using the Wilcoxon signed-rank test as a non-parametric method appropriate for paired measurements and small samples, with statistical significance defined as $p < 0.05$.

Ethical considerations were addressed through clear communication about program objectives, procedures, expected benefits, and the voluntary nature of participation. Informed consent was obtained from all participants prior to data collection, and participants were informed of their right to withdraw at any stage without any negative consequences. Confidentiality was maintained by limiting access to collected data to the program team and by ensuring that analysis and reporting did not include direct personal identifiers.

Figure 1
Stages of community service activity implementation



RESULTS AND DISCUSSION

Implementation process and participant engagement

The educational intervention achieved its immediate process objective by delivering community-based waste management education through interactive, participatory activities in Balocci Village. The program was coordinated by lecturers from the Health Administration Study Program, Faculty of Sport and Health Sciences, Makassar State University, and implemented using complementary methods, including delivery of educational materials, installation of educational posters, and placement of an educational board on waste management (see [Figure 2](#)). The content covered fundamental and practical themes, including definitions and types of waste, health and environmental impacts of improper waste handling, and simple, safe, and environmentally friendly household waste management practices (Rosa et al., 2022). This design was intentionally oriented toward empowerment by providing information that is easily understood and readily applicable in daily routines, consistent with the goal of strengthening community capacity rather than merely transferring knowledge (Kurniawati et al., 2023).

During implementation, the 22 participants, cadres, residents, and community leaders, demonstrated strong engagement, reflected by active questioning, experience sharing, and interactive discussion. This participation suggests that the educational approach was perceived as relevant to local concerns and delivered in an accessible manner. In community-based environmental education, such responsiveness is an important indicator of program acceptability and feasibility, because learning processes that resonate with lived experience are more likely to be internalized and translated into routine practice (Kurniawati et al., 2023). The observed enthusiasm also indicates that involving cadres and leaders can strengthen the social legitimacy of educational messages and create a supportive learning environment for collective reflection and problem-solving within the community context.

The participatory and interactive character of the activity aligns with evidence that two-way educational interactions are central to effective health promotion, particularly when the intended outcome includes voluntary adoption of healthier and more environmentally responsible behaviors (Mardalena et al., 2025; Rofiki & Famuji, 2020). In this program, interactive discussion and participant experience-sharing likely functioned as a mechanism for contextualization—helping participants connect waste management concepts to local practices and constraints—thereby improving message salience and perceived usefulness. This mirrors findings that education designed around community needs and practical applicability can enhance engagement and support behavior adoption beyond the session itself (Rahmayanti et al., 2025). Compared with more didactic outreach models, the combination of facilitated discussion and locally relevant content may offer an advantage in strengthening comprehension and motivation, particularly in communities where waste-related practices are rooted in long-standing habits and limited exposure to health–environment linkages (Aprisanti et al., 2024).

Figure 2
Process of educational activities



Note: A) Documentation of educational activities with participants, (B) Installation of educational posters, (C) Educational board on waste management

Table 1
Comparison of knowledge levels before and after education

Knowledge Classification	Pre-Test (n)	Pre-Test (%)	Post-Test (n)	Post-Test (%)	P-value
Good	14	64	22	100	0.003
Poor	8	36	0	0	
Total	22	100	22	100	

Process findings indicate that participatory delivery is feasible and acceptable for community waste management education in Balocci Village and may provide a replicable template for similar rural settings. Practically, high engagement suggests readiness for community-driven action, which is essential for sustained improvements in household waste practices. Scientifically, strong participation supports the plausibility that subsequent knowledge gains were not incidental but occurred within an enabling learning environment characterized by interaction, relevance, and social reinforcement, which are important determinants of educational effectiveness in health promotion interventions (Rofiki & Famuji, 2020). However, because process indicators do not directly measure long-term practice adoption, these results also underscore the need for follow-up mentoring or community monitoring to ensure that engagement translates into consistent waste management behaviors (Rahmayanti et al., 2025).

Knowledge improvement after education

The primary outcome of the program was improved participant knowledge regarding waste management following the educational intervention. Pre-test and post-test results (see Table 1) showed that prior to education, 36% (8/22) of participants were classified as having poor knowledge, while 64% (14/22) were in the good-knowledge category. After the intervention, all participants (22/22; 100%) were classified as having good knowledge, and none remained in the poor-knowledge category (0%). This shift indicates that the educational content, delivery, and reinforcement strategy effectively addressed knowledge gaps within the participating groups. The baseline presence of poor knowledge is consistent with the notion that limited initial understanding may be associated with habitual waste management practices that do not fully consider health and environmental risks (Aprisanti et al., 2024). The post-intervention elimination of the poor-knowledge category suggests that the educational activity was appropriately pitched, understandable, and aligned with the participants' informational needs. To verify whether the observed improvement was statistically significant, a Wilcoxon test was applied to paired pre-test and post-test measures, yielding a p-value of 0.003. Because this value is below $\alpha = 0.05$, the analysis indicates a significant difference in knowledge before and after the educational intervention. Thus, the program met its immediate learning objective by producing measurable knowledge gains among cadres, residents, and community leaders participating in the activity.

The significant pre-post knowledge improvement aligns with prior studies showing that educational interventions can increase knowledge related to environmental health and waste management, particularly when learning objectives are clear and evaluation is structured around pre-test and post-test assessment (Pradani et al., 2025; Fakhriyah et al., 2025). In this program, an added advantage is the integration of multiple educational modalities—oral delivery of materials supplemented by posters and educational boards—which likely strengthened comprehension and recall compared with single-channel education alone (Meilani & Harianti, 2024). Moreover, the activity was implemented as an interactive learning process, consistent with health promotion models emphasizing voluntary behavior change through knowledge, awareness, and dialogue rather than coercion (Mardalena et al., 2025; Rofiki & Famuji, 2020). These features may explain why the intervention not only improved mean knowledge but also shifted the entire group out of the poor-knowledge category, indicating broad reach and equity of understanding among participants.

From a public health perspective, improved knowledge is a critical proximal determinant for reducing environmental health risks associated with improper waste disposal, such as vector breeding

and contamination pathways, particularly when participants include cadres and leaders who can diffuse practices and norms across households. Practically, achieving 100% good-knowledge classification suggests that the educational package is suitable for rapid capacity building in similar community settings. Scientifically, the significant Wilcoxon result ($p = 0.003$) supports the inference that the intervention contributed to knowledge change rather than random variation, although causal attribution remains limited by the absence of a comparison group. An important next step for strengthening the evidence base is to extend evaluation beyond immediate post-test outcomes to include behavioral indicators (e.g., household sorting, safe disposal practices, participation in community waste initiatives) and to examine whether knowledge gains are maintained over time (Rahmayanti et al., 2025). Such follow-up would clarify whether knowledge improvements translate into sustained practice change, which is the ultimate pathway to health and environmental benefit (Mardalena et al., 2025).

Role of visual media and social drivers supporting sustainability

A notable feature of this program was the deliberate pairing of interactive education with visual reinforcement through posters and educational boards placed in strategic locations, enabling continuous access to key messages after the session. This design reflects an explicit sustainability orientation: rather than relying solely on one-time education, the program created persistent informational cues within the community environment. Visual media can strengthen environmental education by increasing accessibility, enabling quick comprehension of complex ideas, and supporting retention through repeated exposure (Januchowski-Hartley et al., 2025; Thomas et al., 2021). Participatory and community-based visual approaches, including methods such as photovoice and digital storytelling, are also recognized for surfacing local knowledge, increasing citizen participation, and translating environmental concepts into relatable narratives that support stewardship (Csesznek, 2021). In addition, visual literacy tools such as infographics are known to enhance understanding and equitable access to information in both formal and non-formal learning contexts (Hines et al., 2020; Byrnes et al., 2022).

Beyond media, participant composition (cadres, residents, and leaders) represents a potentially important driver of sustained action. Leadership and trained cadres can translate knowledge into routine practice, model pro-environmental behaviors, and mobilize collective participation in locally appropriate waste governance mechanisms (Hakim & Hidayati, 2023). In community waste initiatives, such embedded leadership can generate ownership and social capital, which are frequently identified as prerequisites for continuity and adaptation over time (Khotimah et al., 2023).

The program's emphasis on knowledge strengthening and reinforcement cues is consistent with behavior change theories commonly applied to waste management. The Theory of Planned Behavior (TPB) posits that behavior is shaped by intention, which is influenced by attitudes, subjective norms, and perceived behavioral control, and is often strengthened by incorporating environmental knowledge and personal norms to improve explanatory power (Wu et al., 2022). Evidence from diverse settings indicates that perceived control, personal norms, and environmental values contribute to intentions to separate, reduce, and responsibly manage waste, with TPB constructs mediating the translation of intention into practice (Oduro-Appiah et al., 2022). Complementary perspectives such as the Value-Belief-Norm (VBN) theory and moral norms further explain pro-environmental motivation and strengthen prediction of household waste practices (Liu et al., 2022). Integrative models combining TPB with VBN, self-identity, or moral norms have demonstrated improved prediction of waste sorting, food waste reduction, and e-waste recycling intentions, thereby informing the design of targeted interventions and incentives (Chen, 2022; Pongpunpurt et al., 2022; Yu & Mangmeechai, 2023).

Within this theoretical framing, the program's multi-component approach offers a practical advantage: interactive education can shape attitudes and perceived relevance, involvement of cadres and leaders can strengthen subjective norms and community expectations, and visual media can function as ongoing cues that support maintenance and habit formation. Prior empirical work

also supports the use of visual educational media in improving understanding and awareness of proper waste management, reinforcing the rationale for poster and board installation as a continuity mechanism (Meilani & Harianti, 2024). Additionally, education and capacity-building interventions—including structured courses and cadre mentorship—are recognized for strengthening competencies and enabling multi-stakeholder collaboration in line with circular economy goals (Ansari et al., 2024; Pisuttu et al., 2024).

These findings indicate that strengthening “waste management literacy” through an integrated educational package may be a realistic and scalable pathway toward improved community waste practices, particularly when technological solutions are not readily accessible. Practically, maintaining posters and boards in high-traffic locations can sustain message exposure and support continued recall, while cadres and leaders can institutionalize norms through routine community activities and informal monitoring (Hakim & Hidayati, 2023). Scientifically, the results support a plausible mechanism linking educational reinforcement and social diffusion to knowledge and potential behavior change, consistent with TPB- and VBN-informed pathways (Liu et al., 2022; Wu et al., 2022). However, because the current evaluation focused on knowledge outcomes, future work should assess behavioral and environmental indicators and examine enabling conditions and barriers for sustained practice, including governance support, incentives, and context-specific constraints that differ across rural, peri-urban, and urban settings (Fronde et al., 2024; Mugambe et al., 2022; Kurniawan et al., 2021; Sugiharjo et al., 2025). Embedding the program within local waste governance initiatives (e.g., community networks, cadre systems, or community-based waste organizations) may further reinforce continuity, generate ownership, and enable adaptive improvement over time (Khotimah et al., 2023).

CONCLUSION

The “Smart Waste Management, Smart Environment Protection” community service program demonstrated measurable effectiveness in strengthening community knowledge and understanding of proper, environmentally friendly waste management. Through participatory educational implementation, the program increased public awareness of the health and environmental consequences of improper waste handling, thereby achieving its primary objective and establishing an essential precondition for improved waste-related attitudes and behaviors. The integration of visual educational media—posters and information boards—functioned as continuous reinforcement, supporting message retention and providing ongoing access to practical guidance within the community environment. These findings indicate that community-based education can serve as a strategic health promotion intervention in rural settings by addressing upstream behavioral determinants that contribute to environmental contamination and related health risks. Nevertheless, because the present evaluation focused on immediate knowledge outcomes, further mentoring and longitudinal assessment are recommended to determine sustained practice adoption, identify barriers and enabling factors, and optimize program scalability for broader implementation.

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AUTHORS' CONTRIBUTION

Irfan Kurniawan contributed to the conceptualization and study design, led the manuscript drafting, and supervised the overall research workflow. Samsiana contributed to literature review and assisted in revising the manuscript for important intellectual content. Mujtahidah contributed to data collection and supported data interpretation. Andi Atssam Mappanyuki contributed to data analysis and assisted in manuscript review and editing. Muhammad Ridha Afdhal contributed to methodology development and supported validation of findings. All authors read and approved the final manuscript.

COMPETING INTEREST

The author(s) declare no potential conflict of interest with respect to the research, authorship, or publication

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