

DEVELOPMENT OF A BEHAVIOR CHANGE TO REDUCE MICROPLASTIC EXPOSURE IN COASTAL COMMUNITIES

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ABSTRACT

Coastal communities face high vulnerability to microplastic exposure due to widespread environmental contamination and limited risk awareness, prompting this study to develop, validate, and evaluate a behavior-change-oriented educational module to reduce such exposure. This study applied a Research and Development (R&D) approach comprising the stages Analyze, Design, Develop, Implement, and Evaluate. The analysis phase included a behavioral survey (n = 111) and focus group discussions with key stakeholders. The module underwent expert validation and was piloted among 29 coastal residents, with behavior measured using pre-post instruments. Quantitative data were analyzed using paired t-tests or Wilcoxon tests, while qualitative data were thematically analyzed to assess feasibility and acceptability. Survey and FGD findings indicated low knowledge, incorrect risk perceptions, and environmentally unsafe practices, exacerbated by structural constraints such as limited waste services. The validated module demonstrated high content validity (S-CVI/Ave = 93%; S-CVI/UA = 86%). Pilot implementation showed a significant improvement in knowledge ($Z = -4.372$; $p < 0.001$) and attitudes ($t = -2.559$; $p = 0.016$). Qualitative evaluations confirmed that the module was easy to use, contextually relevant, and operationally feasible for community-based health education. These findings align with evidence that structured, visual, and participatory learning strategies effectively promote environmental health behavior change. Conclusion this research the behavior-change educational module effectively improved microplastic-related behaviors among coastal communities and is feasible for broader community-empowerment implementation provided that sustained cross-sectoral support is ensured.

Keywords: behavior change, coastal community, education module, environmental health, microplastic exposure

Introduction

Microplastic exposure is increasingly recognized as a rapidly emerging public health issue, particularly in coastal communities that rely heavily on marine resources for daily food consumption. Microplastic particles measuring < 5 mm have been detected in seawater, sediments, and marine organisms consumed by humans, such as fish and shellfish, making them a major route of exposure (Alberghini et al., 2023). Recent studies indicate that microplastic exposure can induce inflammatory responses, oxidative stress,

hormonal disruption, and potentially elevate the risk of non-communicable diseases, including metabolic disorders, chronic inflammation, and cardiovascular diseases (2,3).

In Indonesia, coastal regions are particularly vulnerable to microplastic contamination due to high levels of single-use plastic consumption, low environmental literacy, and suboptimal waste management systems (Muntaha Mardhatillah, Mutia Kahanna, 2025). Several studies conducted in coastal areas of Sumatra have reported the presence of microplastics in commonly consumed fish species. For instance, in the Belawan Estuary (North Sumatra), microplastic contamination is reported to be high in aquatic biota, dominated by fibers, fragments, films, and pellets (Muhtadi et al., 2025). Furthermore, research in the coastal waters of Padang (West Sumatra) identified microplastics in commercially caught trawl fish through FTIR analysis, with polyethylene terephthalate (PET) being the predominant polymer (Edwin et al., 2023).

Microplastic-related research in Riau Province over the past five years has primarily focused on mapping microplastic types and abundance in aquatic environments. Studies have documented the dominance of fibers, fragments, and films in the Siak River, with the highest concentrations observed in downstream areas characterized by dense human activities (Tampubolon et al., 2024). In other locations, such as the Sail River, fibers were most frequently detected in water samples, whereas fragments were more dominant in sediments (Widyadhana et al., 2024). While these studies provide important insights into the extent of microplastic contamination, they have not introduced intervention strategies aimed at reducing microplastic exposure through behavioral change approaches.

Moreover, research examining the relationship between environmental factors, community behaviors, and health outcomes in Riau Province remains limited, particularly studies oriented toward developing behavior-based interventions. A study conducted in Pekanbaru demonstrated that environmental conditions and daily behaviors significantly influence community health risks (Zahtamal et al., 2024). However, this research did not address the role of emerging contaminants such as microplastics, nor did it explore behavior-change-based mitigation strategies.

Behavior-based approaches have been proven effective in improving healthy and environmentally friendly practices across various public health contexts. Educational modules developed using behavioral theories such as the Health Belief Model (HBM) and the Theory of Planned Behavior (TPB), and designed through participatory processes tailored to local contexts, have the potential to serve as effective tools for encouraging communities to reduce plastic use, improve waste management practices, and adopt safer seafood-consumption behaviors (10, 11,12). However, to date, no studies in Indonesia have specifically developed and tested a behavior-change module aimed at reducing microplastic exposure in coastal communities. Based on these gaps, the present study aims to answer two key questions: (1) What is an appropriate structure and content of a behavior-change educational module to reduce microplastic exposure in coastal communities? and (2) To what extent is the module effective in improving community behaviors related to microplastic exposure reduction?

Methods

This study employed a Research and Development (R&D) approach to produce and evaluate the effectiveness of an educational product in the form of a behavior-change

module designed to reduce microplastic exposure in coastal communities. The R&D method was selected to ensure that the module development process was conducted systematically, from needs assessment to intervention evaluation, so that the final product would be valid, feasible, and aligned with the context of the target population. The module development followed the ADDIE model (Analyze, Design, Develop, Implement, Evaluate), a widely used and structured instructional design framework that ensures each development stage proceeds logically, sequentially, and responsively to user needs. In accordance with the ADDIE principles, each stage was carried out iteratively and was open to revision if new insights or feedback emerged during implementation (Adeoye et al., 2024).

The study was conducted in Sungai Apit District, Siak Regency, Riau Province, a coastal area with high levels of microplastic exposure due to daily community activities that rely heavily on river and marine resources. The research subjects consisted of quantitative respondents and qualitative informants. In the initial survey phase, 111 adult respondents aged 18–60 years who had resided in the area for more than one year and provided informed consent completed a questionnaire assessing knowledge, attitudes, and practices (KAP) related to microplastics. Participants were selected using purposive sampling to ensure representation from community members with high exposure risk to microplastics. For the module trial, a sample of 29 individuals meeting the same inclusion criteria was selected, excluding those with cognitive impairments that could hinder comprehension of the module content. In addition, the study involved 15 informants in in-depth interviews and focus group discussions (FGDs), including health workers, environmental cadres, community leaders, fishermen, housewives, and relevant policymakers. Informants were selected using purposive sampling to obtain rich and contextually grounded perspectives on conditions within coastal communities.

The primary variables in this study included the intervention in the form of module use as the independent variable, and changes in knowledge, attitudes, and practices related to microplastics as the dependent variables or outcomes. Knowledge was measured using a true–false scoring system; attitudes were assessed using a Likert scale; and practices related to microplastic exposure reduction were measured using numerical self-report items.

The research instruments consisted of a KAP questionnaire and learning outcome test, developed based on a literature review and field-based needs assessment. Content validity of the module and instruments was assessed by two subject-matter experts, a language expert, and a field practitioner. The Content Validity Index (CVI) at both item-level and scale-level was used to ensure alignment between content and educational objectives. The feasibility level of the module based on expert validation was categorized into five levels. A score of 81–100% was classified as very valid, indicating the module was suitable for use without major revisions. Scores of 61–80% were categorized as valid, meaning the module was feasible with minor improvements. Scores of 41–60% indicated low validity, requiring substantial revisions. Scores of 21–40% reflected invalidity, showing that the module was not suitable and required comprehensive redesign. Meanwhile, scores of 0–20% indicated very low validity, meaning the module did not meet feasibility standards and required complete revision before use (Cocchi et al., 2023).

All expert feedback was analyzed qualitatively and incorporated into the refinement of the module prior to implementation.

The research procedures followed the ADDIE stages sequentially. In the Analyze stage, surveys and interviews were conducted to explore community understanding and information needs regarding microplastic exposure risks. The Design stage involved structuring the module, selecting educational approaches, drafting core materials, and determining the module format in both printed and digital versions. The Develop stage focused on drafting the module and expert validation. Once deemed feasible, the Implement stage involved a limited trial with 29 participants to assess comprehension, practicality, and implementation challenges. The Evaluate stage assessed module effectiveness using quantitative methods (pre-test and post-test analysis) and qualitative methods through interviews and FGDs.

Quantitative data were analyzed using SPSS. The analysis process began with data cleaning to address missing values and outliers, followed by Shapiro Wilk normality testing for numerical data. Descriptive statistics were presented as means and standard deviations for normally distributed data, and medians with minimum–maximum values for non-normal data. Module effectiveness was tested using paired t-tests for normally distributed variables or the Wilcoxon signed-rank test for non-normal distributions. All tests were two-tailed with a significance level of 0.05. Effect sizes were reported to provide insight into the magnitude of changes following the intervention. Meanwhile, qualitative data from interviews and FGDs were analyzed using thematic analysis following the procedures outlined by Braun and Clarke, including transcription, coding, theme development, and interpretation. Investigator triangulation was employed to ensure credibility of the analysis. All research procedures were approved by the Health and Medical Research Ethics Committee of the Faculty of Medicine, Universitas Riau (approval number 053/UN19.5.1.1.8/UEPKK/2025). Participation was voluntary, with written informed consent obtained after comprehensive explanation of the study.

Results

This study aims to develop a behavior-change module to reduce microplastic exposure in coastal communities. In the analysis phase, an initial survey was conducted involving 111 adults with a median age of 48 years to obtain an overview of their knowledge, attitudes, and practices (KAP) related to microplastics. The survey findings were used to explore behavioral patterns and information needs essential for module development. The results revealed that substantial misconceptions regarding microplastics persist within the community. Most respondents demonstrated limited to moderate understanding of microplastics, accounting for 60.4%. The findings further indicated that the knowledge of coastal communities regarding microplastics remains low and is characterized by several fundamental misconceptions.

A large proportion of respondents believed that microplastics refer to all commonly used plastic items, rather than very small plastic particles that result from plastic degradation or the release of synthetic fibers. In addition, many community members assumed that burning plastic waste in their yards is a safe and effective method to reduce plastic waste, despite the fact that this practice can generate harmful pollutants and does not eliminate

microplastic risks in the environment. This misconception was further reinforced by respondents' attitudes, as many continued to perceive burning plastic waste as a safe and environmentally friendly solution.

Other findings showed that the community was not aware that household activities, such as washing nylon or polyester clothing, can release microplastic fibers into wastewater, which subsequently contributes to coastal pollution. Misconceptions were also evident regarding the safety of marine products. Many respondents believed that all seafood, particularly fish from offshore areas, is free from microplastics, despite evidence from various studies indicating that marine organisms are among the major reservoirs for microplastic accumulation. Additionally, the daily use of single-use plastic bags was not perceived as having any health impact, indicating a low level of understanding of microplastic exposure pathways and associated long-term risks. Although some respondents acknowledged that microplastics may pose health hazards, their awareness was not accompanied by accurate knowledge about the sources, mechanisms of release, and exposure routes of microplastics in everyday life.

These patterns of knowledge and attitudes were reflected in the community's daily practices related to waste management and plastic use. The study identified that practices aimed at reducing plastic consumption and preventing microplastic exposure remain limited. Most community members did not bring reusable shopping bags when visiting markets, shops, or kiosks, leading to continued reliance on single-use plastic bags. This behavior was compounded by the prevalent consumption of bottled drinking water in single-use plastic containers, indicating that efforts to reduce plastic use have not been integrated into daily habits. Additionally, many community members reused discarded plastic containers for various household purposes, a practice that may unintentionally increase exposure to hazardous chemicals and microplastic release due to plastic degradation.

Another notable finding was that most community members continued to burn plastic waste in their yards as a quick solution to reduce waste volume. Furthermore, participation in ideal waste management activities, such as waste banks, recycling initiatives, or river and coastal clean-up movements remained very low. This lack of engagement suggests that collective efforts to reduce plastic waste in coastal areas have not been implemented optimally.

Findings from the focus group discussions (FGDs) involving community leaders, village heads, primary healthcare (Puskesmas) personnel, and representatives from the Environmental and Forestry Agency (DLHK) revealed that the behaviors and perceptions of coastal communities regarding plastic use and microplastic risks continue to be shaped by longstanding habits, ease of access, and limited educational interventions. Community leaders and local authorities acknowledged that although people recognize the environmental harms associated with plastic, dependence on plastic remains high because it is perceived as practical and difficult to replace. Explanations provided by community elders, such as the past use of *upih* (areca sheath) and banana leaves, illustrated a behavioral shift from environmentally friendly traditional practices toward widespread plastic consumption. However, this transition has not been accompanied by improved awareness, resulting in an indifferent attitude toward the long-term risks of

microplastic exposure.

FGDs with health promotion and environmental health officers at Puskesmas indicated that specific education or outreach regarding the dangers of microplastics has never been conducted. Existing educational activities focus solely on general waste management and do not explicitly address microplastic-related issues. This gap has contributed to limited and inaccurate public understanding, including habits such as reusing single-use plastics, heating food in plastic containers, and discharging laundry wastewater directly into drainage channels that flow into rivers or the sea. Informants also highlighted that open burning of plastic waste remains widespread, particularly in areas without formal waste collection services. In several coastal villages, up to 40% of residents still dispose of waste directly into the sea, including single-use diapers, which significantly contribute to pollution.

FGDs with DLHK representatives and subdistrict staff further revealed that waste-related problems in coastal areas are not solely linked to community behavior but are also influenced by weaknesses in the public service management system. DLHK informants noted that waste-processing facilities in coastal regions often operate suboptimally, raising concerns that a portion of collected waste may ultimately end up in rivers or the ocean. This finding was reinforced by field observations showing the presence of undegraded waste, even after being buried for years. The absence of regulations restricting the circulation of single-use plastics was also perceived as a key factor exacerbating the accumulation of non-biodegradable waste in coastal environments. From the perspective of the village administration, no specific regulations on waste management are currently in place, and initiatives such as waste banks, once established are now inactive. Waste collection services cover only about 50% of households, leaving many residents to either dispose of waste into waterways or burn it.

The FGDs also underscored that challenges in reducing microplastic exposure in coastal communities operate across multiple levels. Subdistrict and DLHK informants emphasized that coastal populations are among the most affected groups because they receive waste flows from upstream areas, while levels of awareness remain low despite general knowledge that plastic is harmful. Among fishing communities, dependence on plastic is particularly high because nearly all work equipment is plastic-based; thus, reduction efforts should focus on promoting proper management rather than prohibition. From a community empowerment perspective, FGD participants agreed that integrated health post (*posyandu*) cadres, *posyandu* activities, religious gatherings such as *pengajian* and *majelis taklim*, local cultural activities such as *kompang* or *rebana*, and video-based social media are the most effective channels for microplastic education. Subdistrict officials expressed readiness to conduct tiered socialization through the subdistrict head, village heads, and neighborhood leaders, provided that standardized materials, such as education modules are available. Community health cadres also indicated their willingness to be trained as trainers to disseminate microplastic-related messages during various community events. Overall, these findings highlight that reducing microplastic exposure requires cross-sectoral coordination, the availability of appropriate educational materials, and the utilization of existing social structures and media within coastal communities.

Based on the needs assessment derived from behavioral surveys and FGDs, a clear gap was identified in the knowledge, attitudes, and practices of coastal communities regarding microplastic exposure, indicating a pressing need for structured educational interventions. This situation underscores the importance of developing a module as a learning instrument designed to correct misconceptions, enhance risk awareness, and guide safer and more sustainable behavioral change within the context of coastal life. The module was subsequently developed with consideration of local characteristics, preferred educational media, multi-stakeholder roles, and the potential of community health cadres and healthcare institutions as key dissemination agents, ensuring that the intervention can be implemented effectively and contextually at the community level.

At the design stage, the researchers began formulating the structure and components of the educational module entitled “*Environmental Awareness for Reducing Microplastic Exposure in Coastal Communities.*” The module was developed using a comprehensive educational approach, integrating conceptual elements with practical strategies for reducing microplastic exposure in the daily lives of coastal populations. The following section outlines the design process and the development of the module’s substantive components:

1. Module Cover Design

During the design phase, the researchers developed the visual layout of the module as a representation of the identity and core message of the educational intervention. The cover design features illustrations of coastal community life, including activities related to plastic waste management, symbolizing collective efforts to reduce microplastic exposure. The visuals were selected to reinforce behavioral change messages and to capture the attention of target users with diverse levels of literacy. Additionally, the use of bright colors and contextually relevant illustrations was intended to create an emotional connection between the module content and the everyday realities of coastal communities, thereby enhancing acceptance and increasing users’ intention to engage with and learn from the module. The module cover can be seen in Figure 1.

2. Module Structure and Organization

The structure of the module was organized hierarchically and systematically to ensure ease of navigation and consistency in the learning flow. The module consists of four main chapters: Introduction; Fundamental Concepts of Microplastics and Associated Risks; Environmental and Health Impacts of Microplastics; and Risk Behaviors and Recommended Behavioral Changes. Each chapter was designed to provide a logical progression of learning, beginning with a foundational understanding of microplastics, followed by an explanation of the risks, and concluding with behavioral approaches that can be modified within the community.

The introductory section provides the conceptual foundation, objectives, benefits, and target users of the module. The conceptual chapter presents definitions, characteristics, exposure sources, and mechanisms of microplastics within coastal ecosystems. The chapter on environmental and health impacts summarizes the latest scientific evidence regarding the toxicological effects of microplastics. Meanwhile, the behavior-focused chapter identifies risky behaviors observed through the KAP survey and FGDs, and offers safe and sustainable behavioral alternatives. Overall, this structure was designed to

support a stepwise, applicable, and contextually relevant educational approach tailored to coastal communities.

3. Components of Tables and Figures/Illustrations

The module includes 24 tables and 25 figures/illustrations that serve as visual learning aids. The tables contain detailed components of the educational implementation, participatory methods, material delivery flow, categories of hazardous substances associated with microplastics, and recommended behavioral changes. The figures and illustrations were developed to explain abstract concepts such as microplastic structure, environmental movement pathways, routes of human exposure, and examples of risky behaviors relevant to the study findings. The use of visual elements aims to enhance conceptual understanding and facilitate learning for participants with varying levels of literacy.

4. Supporting Appendices of the Module

The appendices were prepared as operational tools to support the implementation of educational activities in the field. All appendix components were designed to strengthen participant engagement, enhance material delivery effectiveness, and ensure the sustainability of behavior change following the intervention. One of the key components is the educational game “*Siapa Cepat Dia Peduli!*” which serves as an icebreaker to create an interactive atmosphere, facilitate cognitive readiness, and increase participant engagement prior to the core session on microplastic exposure. Additionally, the “*Janji Hijau!*” game functions as a behavioral commitment strategy, where participants write or express specific actions they intend to change after the educational session. This approach is based on the principles of behavioral activation, which have been shown to be effective in strengthening community-based behavioral change intentions.

In addition to the games, the appendix provides a detailed rundown of the educational implementation, including the sequence of activities from the opening, warm-up games, core material delivery, group discussions, to closing. This rundown ensures that facilitators can manage the session in a structured manner and in alignment with the allocated time. The appendix also includes a Follow-Up Action Plan (RTL) format, designed as a tool for participants to formulate both personal and communal commitments to behavioral change after the training. The RTL is essential for maintaining continuity of the intervention and facilitating long-term monitoring of new behavior adoption. Taken together, these appendix components reinforce the module as an educational instrument that is not only informative but also applicable and capable of driving real action at the community level.

The appendices also include a table outlining the evaluation methods used to assess the module’s effectiveness through a pre–post design, using instruments to measure changes in participants’ knowledge, attitudes, and practices related to microplastics. These tools are complemented by process evaluation instruments and feedback forms to assess material delivery quality, content relevance, and participant engagement. The monitoring and evaluation (M&E) system was designed comprehensively, covering input, process, output, and outcome monitoring using measurable indicators and standardized instruments. Input monitoring includes module distribution and the number of trained facilitators, while process monitoring evaluates

participation levels, facilitation quality, and adherence to module guidelines using attendance lists, field supervision, and observation checklists. The field checklist ensures implementation consistency, whereas weekly monitoring reports document achievements, challenges, and recommended improvements, allowing rapid adjustments during program implementation. Integration of quantitative and qualitative data through this triangulated system produces a comprehensive evaluation, enabling assessment of the module not only in terms of learning outcomes but also its implementation effectiveness and long-term sustainability in microplastic exposure reduction efforts in coastal communities.

Following the design stage, the module underwent expert validation involving subject-matter experts and language specialists. Content validation ensured that the module's material was relevant and aligned with the needs of coastal communities, while language validation ensured that the wording was understandable and appropriate for the target users. The validation results indicated that the module met the eligibility criteria, with a score of 93% for the Scale-Level Content Validity Index Average (S-CVI/Ave) and 86% for the Scale-Level Content Validity Index Universal Agreement (S-CVI/UA), signifying that the module was highly suitable for use. The validation also included an assessment of the quality and depth of the materials presented to ensure that all necessary information was appropriately covered.

During the development stage, revisions were made to the module based on feedback from the validators. This validation process was crucial in ensuring that the developed module aligned with community needs and was easily understood and accepted. One key aspect highlighted by the validators was the importance of using language and visuals that are accessible and easily comprehensible to the intended users.

After the module was developed and validated by experts, the trial/implementation phase was carried out among 29 coastal community participants to assess its effectiveness in improving behaviors related to microplastic exposure. The trial began with a pre-test, followed by a series of learning activities, starting with an ice-breaking game, *"Who's Fast, Cares First!"*, designed to explore participants' baseline knowledge about microplastics. Next, participants received three learning sessions: (1) an introduction to microplastics and their sources of exposure delivered through interactive lectures, PowerPoint materials, and a short video accessible at: <https://www.youtube.com/watch?v=v5jg7UvVlhc&t=139s>, 2) the health and environmental impacts of microplastics delivered through lectures, discussions, and case studies; and 3) risky behaviors and safe strategies to reduce exposure through simulation and demonstration activities under the theme *"Smart Plastic Choices & 3R"*. In the following phase, participants engaged in behavior change triggering and motivation building through the *"Commitment Tree"* game, followed by the development of action plans, group discussion, reflection, and post-test.

Statistical analysis showed that the mean knowledge score was 68.24, with data normally distributed at pre-test ($p = 0.840$). After the educational intervention, the median post-test score increased to 83.33, although the data were not normally distributed ($p = 0.000$), therefore the Wilcoxon test was applied. The results indicated a significant increase in knowledge ($Z = -4.372$; $p = 0.000$). For attitude variables, the mean attitude

score was $79.17 \pm \text{SD } 10.02$, which increased to $84.27 \pm \text{SD } 11.85$ after the intervention. Both datasets were normally distributed, with normality tests showing pre-test ($p = 0.617$) and post-test ($p = 0.110$), thus a paired t-test was used. The results showed a significant difference in mean attitude scores before and after the intervention ($t = -2.559$; $p = 0.016$). These findings indicate that the module effectively improved participants' positive attitudes toward reducing microplastic exposure. Overall, the results confirm that the module successfully enhanced the knowledge and attitudes of coastal communities, demonstrating its potential as an applicable educational tool in community-level microplastic risk reduction efforts.

In addition to improvements in knowledge and attitudes, qualitative evaluations from healthcare workers and community health volunteers involved in the trial indicated that the module was easy to understand, relevant, and applicable within the context of coastal community empowerment. Health promotion officers and environmental health staff at the Puskesmas reported that the module provided a systematic and comprehensive guide for implementing behavior-change interventions related to microplastic exposure reduction. The structured educational flow included in the module was found to facilitate the delivery of information, guide discussions, and support behavioral reflection more effectively for health workers, cadres, and other individuals responsible for community education.

Further evaluation revealed that the module's effectiveness could be enhanced if accompanied by more intensive monitoring mechanisms and sustained support from all stakeholders. In practice, Puskesmas personnel could conduct periodic follow-up sessions to ensure that environmentally friendly behaviors introduced through the module continue to be practiced by the community. The action plan (RTL) component is recommended to be followed systematically to assess the long-term success of the educational process. Although the module demonstrated effectiveness in the specific coastal community where the study was conducted, further research is needed to examine the replicability and adaptability of its behavior-change strategies across coastal environments with different social, cultural, and ecological characteristics. Overall, the module successfully formulated a systematic and evidence-based approach to reducing risky behaviors related to microplastic exposure in coastal communities. The strategies incorporated in the module emphasize a combination of environmental literacy improvement, strengthening internal motivation, and facilitating gradual preventive behavioral practices. These strategies should be further tested on a larger population scale to ensure broader effectiveness and sustainability across diverse coastal settings.

Discussion

Findings from the situational analysis showed that coastal communities still have low levels of knowledge and attitudes related to microplastics, accompanied by several important misconceptions, such as the belief that all plastic products are microplastics and the assumption that burning waste is a safe way to reduce garbage. This pattern aligns with environmental behavior studies indicating that limited knowledge and incorrect social norms tend to reinforce environmentally harmful practices in at-risk communities (Utari & , N.I. Hawa, G. Fizulmi, 2024). Furthermore, the low awareness of exposure

pathways, including the release of microfibers during the washing of synthetic clothing is consistent with scientific evidence demonstrating that domestic activities are a significant source of microplastic pollution in aquatic environments (Hazal et al., 2024). The daily practices of coastal communities, which still rely heavily on single-use plastics, the reuse of plastic containers, waste burning, and the disposal of garbage into rivers or the sea, indicate not only knowledge gaps but also structural barriers such as limited waste management services, lack of processing facilities, and the absence of local policies restricting single-use plastics. These findings are similar to international reports showing that behavior change cannot be achieved through education alone but requires multilevel interventions that integrate infrastructure improvements, norm strengthening, and context-based education (Nuojuwa et al., 2022). Conditions in Indonesian coastal areas are further exacerbated by evidence that local marine biota have been contaminated with microplastics, increasing exposure risks through the food chain (Edwin et al., 2023).

FGD findings also emphasized the need for a structured and participatory educational approach, utilizing local communication channels such as *posyandu*, religious gatherings, and community health volunteers. The growing awareness that microplastics had never been included in previous health education activities reinforces the urgency of developing an educational module capable of correcting misconceptions, improving risk perception, and offering realistic alternatives for coastal communities. Recent evidence highlights that educational interventions designed in a participatory manner and integrated within local service systems are more effective in promoting sustainable behaviors (Nuojuwa et al., 2022). Thus, the educational module developed in this study has the potential to serve as an important instrument to strengthen behavior change and reduce microplastic exposure in coastal communities.

The module design phase shows how educational content was comprehensively formulated to address gaps in knowledge, attitudes, and practices identified during the situational analysis. The visual approach and systematic content structure are consistent with recent research emphasizing the importance of educational materials that are contextual, engaging, and tailored to the target group's literacy level to enhance community involvement and understanding of microplastic issues (Oliveira et al., 2024). The use of illustrations, bright colors, and visuals based on coastal realities supports the principles of place-based education, which has been shown to improve the acceptance of environmental messages among at-risk communities. The module also integrates the latest scientific developments regarding the sources, movement, and impacts of microplastics on humans and ecosystems, thereby strengthening its relevance and evidence-based foundations in the coastal context.

The module's tiered structure from basic concepts to behavior change recommendations aligns with behavioral learning models that position risk understanding as the starting point for change. Research shows that the most effective environmental interventions combine risk information delivery, attitude formation, and the provision of behavioral alternatives that fit the target community's socio-cultural context (Groh et al., 2019). Additionally, the integration of risky behaviors identified in the KAP survey and FGD demonstrates that the module is not only theory-based but also responsive to the community's real needs. The inclusion of tables, illustrations, and practice examples

strengthens the active learning components, which are recommended in environmental health education to enhance knowledge retention and reduce misconceptions (Deng et al., 2020).

Appendix components including educational games, action plan (RTL) formats, educational rundown, and monitoring and evaluation instruments show that the module is not only designed as an informational medium but also as a tool to mobilize collective action and ensure sustained behavior change. Behavioral activation and community participation approaches have been shown to be effective in promoting environmental behavior change across various international studies (19,20). A monitoring system that incorporates input, process, output, and outcome assessments strengthens the module's quality as an implementable and replicable instrument. The high expert validation scores (S-CVI/Ave and S-CVI/UA) further support the finding that the module meets content and language feasibility standards, aligning with literature emphasizing that content validation is crucial to ensure the effectiveness of health education interventions before broad implementation (Sarah de Sá Leite et al., 2018). Thus, the design phase demonstrates that this module was developed using scientific, contextual, and participatory approaches that enhance its potential as an effective microplastic education tool in coastal communities.

The findings of this study indicate that the behavior-change-based educational module successfully improved knowledge and attitudes among coastal communities regarding microplastic risks. The significant increases in knowledge and attitude scores are consistent with empirical evidence that structured educational interventions can enhance environmental literacy and risk awareness among populations directly exposed to coastal pollution. Recent studies affirm that visual-based learning, educational games, and interactive discussions are effective in strengthening community understanding of environmental pollutant risks, including microplastics (19,22). This is consistent with adult learning mechanisms that emphasize experience, relevance, and interactivity as key factors influencing information retention. The module integrates all three aspects, enabling optimal learning effects for the target groups.

Beyond knowledge improvement, the study's findings show that participants' attitudes also increased significantly after the intervention. This result aligns with studies showing that educational interventions based on behavior-change theories, particularly TPB and HBM can shift risk perceptions and enhance intentions toward pro-environmental behaviors (11, 24, 25). However, some studies indicate that improvements in pro-environment attitudes do not always translate into long-term sustainable behaviors, especially without support from social and structural factors such as community norms, infrastructure access, and social reinforcement mechanisms (26, 27, 28). Therefore, the emphasis by participants and health workers on the importance of follow-up monitoring and multisectoral support is highly relevant. This indicates that although the module effectively improves cognitive and affective readiness, the success of actual behavior change strongly depends on sustained support systems, including Puskesmas monitoring and involvement of community health volunteers.

The qualitative evaluation indicating that the module is easy to use and highly applicable for health workers is consistent with multiple studies. Research has shown that visual-

based interventions (e.g., illustrations, videos) are highly effective in improving health literacy, especially among low-literacy populations (Mbanda, Njabulo, Dada, Shakila, Bastable, 2021). Recent literature also emphasizes that educational modules with clear facilitation flow and contextual visual materials can be effectively integrated into community empowerment programs, particularly in areas with low literacy or limited access to information (Byla et al., 2024). Nevertheless, studies show that despite improvements in knowledge or attitudes, module effectiveness may decline in communities with differing socio-cultural characteristics, such as local norms surrounding plastic use, social structures, or inadequate infrastructure that inhibits long-term behavior change (Nuojuwa et al., 2022). Thus, recommendations to test the module's replicability in other coastal regions are essential to ensure that adaptations can be made without losing cultural and ecological relevance. Overall, the module fulfills the characteristics of an evidence-based intervention by combining environmental literacy, behavioral activation, and preventive practice. However, long-term implementation requires structural support and cross-site studies to ensure sustainability and scalability.

Conclusion

This study concludes that the behavior-change educational module successfully improved community knowledge, attitudes, and microplastic-related behaviors in coastal populations. The module is valid, feasible, and contextually appropriate for community-based environmental health education, demonstrating strong potential for broader implementation. Future scale-up should be supported by sustained multisectoral collaboration and strengthened monitoring mechanisms to ensure long-term behavioral sustainability.

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Conflict of interest

The authors declare that there are no conflicts of interest financial, academic, or personal that could influence the research outcomes or the preparation of this article.

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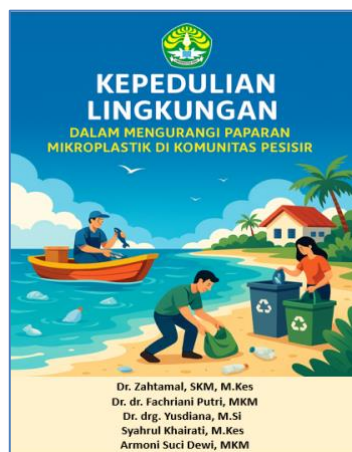


Figure 1. Module cover