



Strengthening Local Residents' Capacity for Community-Based Environmental Monitoring in the Mining Area of Mimika, Central Papua

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ABSTRACT

Mimika Regency, Central Papua, is a socially and ecologically significant area due to its strong connection with mineral mining activities, which require local communities to have adequate environmental literacy and basic monitoring capacity. This community service program aimed to strengthen local residents' understanding of mining-related environmental risks and improve their ability to conduct simple community-based environmental monitoring. The program was conducted in Atuka Village, Mimika Tengah District, Mimika Regency, Central Papua, involving 10 participants consisting of local residents, community leaders, youth representatives, and local community groups. A participatory-educational approach was applied through four stages: needs assessment, environmental literacy education, simple environmental monitoring training, and evaluation followed by action planning. The training materials covered mining-related environmental impacts, reclamation and post-mining concepts, simple water quality observation, dust and noise identification, and community-based environmental reporting. The results showed that participants' understanding increased from an average pre-test score of 49.4 to an average post-test score of 79.8, indicating an improvement of 30.4 points. The program also produced a simple environmental monitoring sheet and an initial plan to establish a community-based environmental monitoring group. These findings indicate that practical environmental literacy training can serve as an initial empowerment model for promoting community participation, transparent communication, and sustainable environmental governance in mining-related areas.

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INTRODUCTION

Mining regions often face a complex relationship between economic development, environmental protection, and community well-being. On the one hand, mineral extraction contributes to regional income, employment opportunities, industrial supply chains, and infrastructure development (Atienza et al., 2021; Azubuike et al., 2023; Sun et al., 2021). On the other hand, mining activities may also generate environmental pressures when land, water, air quality, and local ecosystems are not managed through transparent and sustainable governance (Chaudary, 2025; Giljum et al., 2025; Haroon & Hayyat, 2025). These pressures become more sensitive in areas where local communities depend directly on rivers, land, forests, and surrounding natural resources for their daily lives (Bănăduc et al., 2022; Ewunetu et al., 2021; Ma et al., 2022). In this context, environmental literacy is not merely an educational issue but also a practical capacity that enables communities to understand risks, recognize early signs of environmental change, and participate responsibly in local environmental governance.

Mimika Regency in Central Papua represents an important socio-ecological setting for discussing community participation in mining-related environmental monitoring. Administratively, Mimika is part of Central Papua Province, which was established under Law Number 15 of 2022 concerning the formation of Central Papua Province (Badan Pemeriksa Keuangan Republik Indonesia, 2022). The regency is also widely known as a strategic area associated with large-scale mineral mining activities, particularly because of the presence of the Grasberg mineral district and related mining operations in Papua. The publication of *Kabupaten Mimika Dalam Angka 2026* provides a broader statistical context regarding geography, climate, government, population, and regional economic conditions, all of which are relevant for understanding community development needs in the area (Badan Pusat Statistik Kabupaten Mimika, 2026). Therefore, community empowerment in Mimika needs to be positioned within a balanced framework that considers development benefits, environmental risks, local knowledge, and community rights to participate in environmental protection (Anindhita et al., 2024; Blesia et al., 2021; Mokodompit et al., 2024)

The empirical problem that underlies this community service program is the limited capacity of local residents to document environmental changes in a systematic and communicable way. Many residents living near mining-related areas may observe changes in water color, turbidity, odor, dust intensity, noise, vegetation conditions, or land-use patterns, yet such observations often remain informal and fragmented (Kumi et al., 2023; Ren et al., 2025). Without simple recording tools, local environmental knowledge may be difficult to translate into structured information that can support dialogue with village authorities, government institutions, companies, or academic partners (McEwen et al., 2022; Robins et al., 2022). This condition creates a gap between community experience and formal environmental governance, particularly when technical monitoring is perceived as the exclusive domain of experts or institutions (Brondízio et al., 2021; Michalec et al., 2022; Parsons et al., 2025). For this reason, strengthening local residents' ability to conduct simple environmental monitoring is urgent as an entry point for more inclusive, evidence-informed, and participatory environmental communication (Cooke et al., 2023; Willetts et al., 2022; Zerbian et al., 2024)

The urgency of this topic is also linked to the broader agenda of sustainable mining governance in Indonesia. Environmental management in mining areas cannot rely solely on formal regulation, corporate reporting, or laboratory-based assessment, although these mechanisms remain essential (Boullier & Henry, 2022; Jose et al., 2024; Li et al., 2026). Communities need to understand that reclamation, post-mining planning, water quality observation, dust control, and environmental reporting are part of a wider sustainability framework (Pagouni et al., 2024; Simpson et al., 2025; Tibbett, 2024). The Indonesian Ministry of Energy and Mineral Resources has issued technical guidelines on reclamation and post-mining implementation for mineral and coal mining business activities, indicating that environmental recovery is an integral part of responsible mining governance (Kementerian Energi dan Sumber Daya Mineral Republik Indonesia, 2025). However, regulatory frameworks will be more meaningful when local communities are equipped with basic literacy and participatory skills to understand environmental issues in their own living spaces (Berigüete et al., 2024; Pouresmaieli et al., 2024; Yu et al., 2024). Thus, community-based environmental monitoring should be seen as a complementary empowerment strategy, not as a substitute for formal environmental testing or government authority.

Previous studies have shown that citizen science and community-based environmental monitoring can strengthen public participation in environmental management. Bonney et al. (2023) argued that citizen science provides opportunities for communities to contribute to natural resource monitoring, public awareness, and participatory decision-making. More recent studies have extended this argument by showing that community involvement in environmental observation can support local learning, data generation, and problem-solving in different ecological contexts (Ballard et al., 2024; Taylor et al., 2024; Wright et al., 2021). Citizen-based water quality monitoring can strengthen community water organizations when local participation is connected to decision-making

processes (Cendejas et al., 2021; Gupta et al., 2025; Nath & Kirschke, 2023; Perera et al., 2023; Sholihah & Gharesifard, 2025). Shao and Bishop (2025) similarly found that river-based citizen science projects are commonly directed toward water quality assessment and ecosystem health monitoring. Other studies also demonstrate that citizen science can contribute to environmental awareness, monitoring practices, and knowledge production when local actors are not treated merely as data collectors but as participants in community-based environmental governance (Albagli & Iwama, 2022; Dominguez-Rendón et al., 2024; Freschi et al., 2024; Skarlatidou et al., 2024; Tengö et al., 2021).

Despite the growing body of literature, several limitations remain in previous studies on community-based environmental monitoring. First, many citizen science initiatives are still dominated by ecological or water quality monitoring projects in non-mining contexts, while fewer studies examine simple community monitoring in mining-affected areas (Akbar et al., 2021; Domingo et al., 2024; Florkowska & Bryt-Nitarska, 2026; Kourouma et al., 2023). Second, several studies emphasize data collection and technological systems, but pay less attention to basic environmental literacy, community training, and the use of simple observation sheets for residents with limited access to scientific instruments (Danielsen et al., 2022; Florkowska & Bryt-Nitarska, 2026; Guerrero & Sjöström, 2025; Walker et al., 2021). Third, research on participatory environmental monitoring in mining contexts often focuses on formal committees, institutional arrangements, or company-community relations, whereas small-scale community service programs that build initial monitoring capacity at the village level remain underreported (Miklian & Katsos, 2025). Fourth, studies in the Indonesian mining context still need more empirical examples that connect environmental education, local knowledge, and practical monitoring tools for community empowerment (Kementerian Energi dan Sumber Daya Mineral Republik Indonesia, 2025). These gaps indicate the need for a community-based program that is modest in scale but clear in its educational intervention, measurable outcomes, and practical contribution to local environmental governance.

Based on these considerations, this study aims to strengthen the capacity of local residents in Atuka Village, Mimika Tengah District, Mimika Regency, Central Papua, through environmental literacy education and simple community-based environmental monitoring training. The program was designed to improve residents' understanding of sustainable mining, environmental risks, reclamation and post-mining issues, simple water quality observation, dust and noise identification, and systematic reporting of environmental findings. Theoretically, this study contributes to the discussion of citizen science and participatory environmental monitoring by showing how environmental literacy can become an initial foundation for community involvement in mining-related environmental governance (Mina et al., 2026). Practically, the study provides a replicable model of community service through needs identification, interactive education, observation-sheet training, pre-test and post-test evaluation, and the preparation of a follow-up plan for a community-based monitoring group. In this way, the study offers evidence that local capacity building can support more transparent, responsible, and sustainable environmental communication in mining areas.

METHOD

This study employed a community-based mixed-methods evaluation design with a one-group pre-test-post-test approach. The quantitative component was used to measure changes in participants' understanding before and after the program, while the qualitative component was used to describe participants' responses, practical skills, and follow-up plans during the activity. This design was selected because the study aimed to evaluate a small-scale community empowerment program rather than to compare experimental and control groups. The one-group pre-test-post-test model allowed the researchers to assess knowledge improvement after the same intervention was given to all participants. Meanwhile, qualitative observation and reflective discussion provided

contextual information about how participants understood environmental risks, practiced simple monitoring, and developed ideas for community-based environmental action.

The study was conducted in Atuka Village, Mimika Tengah District, Mimika Regency, Central Papua Province, Indonesia. This location was selected because Mimika has strong social, economic, and ecological links with mineral mining activities, making environmental literacy and community-based monitoring relevant for local residents. The program was carried out during the community service implementation period in 2026, with the exact date adjusted to the official activity schedule. The village setting was considered appropriate because residents' daily experiences with water, dust, noise, land use, and environmental change could be directly connected to the training materials. Therefore, the research location was not only a place for data collection but also an important socio-ecological context for understanding the need for community empowerment.

The population of the study consisted of local residents in Atuka Village and community groups who had social, economic, or ecological connections with environmental issues around mining-related areas. The participants were 10 local residents who joined the complete program from the initial session to the final evaluation. They included community leaders, youth representatives, women's group representatives, village apparatus, and residents who showed concern for environmental issues in their area. Participants were selected using purposive sampling through coordination with local community representatives. The inclusion criteria were voluntary willingness to participate, availability to attend the full program, concern for village environmental issues, and ability to engage in discussion and simple observation practice. Participants who did not complete the whole activity were not included in the pre-test and post-test analysis. The limited number of participants reflects the pilot nature of the program, which was designed to test an initial model of environmental literacy and community-based monitoring training.

Data were collected using four main instruments, namely a pre-test and post-test, a community-based environmental monitoring sheet, an observation checklist, and a reflective discussion guide. The pre-test and post-test were used to measure participants' understanding of five indicators: sustainable mining, environmental impacts of mining, reclamation and post-mining, simple water quality observation, and systematic recording and reporting of environmental findings. The community-based environmental monitoring sheet was designed as a practical tool to record location, date, time, type of finding, visual condition, weather condition, supporting evidence, and proposed follow-up action. The observation checklist was used to assess participants' ability to complete the monitoring sheet during simulation and practice sessions. The reflective discussion guide was used to explore participants' views on the usefulness of the program, perceived environmental problems, and the feasibility of establishing a community-based environmental monitoring group.

The instruments were validated through content review by the community service implementation team, which consisted of lecturers with relevant expertise in mining, civil infrastructure, environmental issues, and community empowerment. The review focused on the relevance of each item to the program objectives, clarity of language for community participants, and suitability of the indicators for simple environmental monitoring in a village context. The pre-test and post-test items were aligned with the training materials to ensure that all measured aspects corresponded to the learning objectives. The monitoring sheet and observation checklist were also reviewed to ensure that they could be used by residents without laboratory equipment or advanced technical skills. Reliability was maintained through standardized administration procedures, the use of identical indicators in the pre-test and post-test, an objective answer key, and consistent scoring on a 0–100 scale. Because this was a pilot community intervention involving 10 participants, formal reliability testing such as Cronbach's alpha was not prioritized; instead, the study emphasized scoring consistency, content relevance, and practical usability of the instruments.

The data collection procedure was conducted through several connected stages. The first stage was needs identification, in which the implementation team discussed with local participants to

identify environmental issues perceived by the community, such as changes in water appearance, dust, noise, and limitations in documenting environmental findings. The second stage was the administration of the pre-test to measure participants' initial understanding of mining-related environmental literacy and basic monitoring concepts. The third stage was the implementation of the educational and training program through interactive lectures, group discussions, case-based learning, simulation, and practice using the environmental monitoring sheet. The training materials covered sustainable mining, mining-related environmental risks, reclamation and post-mining, simple visual indicators of water quality, dust and noise observation, documentation of findings, and reporting mechanisms. The fourth stage consisted of the post-test, observation of participants' monitoring practice, reflective discussion, and preparation of a follow-up plan for community-based environmental monitoring.

The overall research and community empowerment procedure is summarized in Figure 1. The flowchart shows that the activity was designed as a continuous process beginning with community needs identification and ending with a follow-up plan. This structure was used to ensure that the program did not stop at environmental education but also produced practical outputs, including improved understanding, a simple monitoring sheet, and an initial plan for a community-based environmental monitoring group.

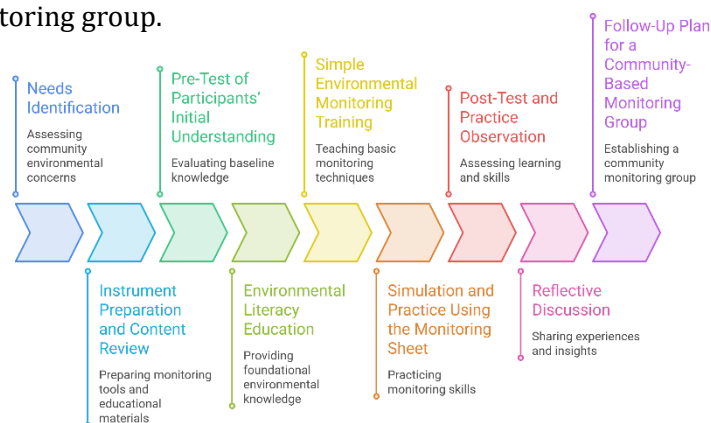


Figure 1. Flowchart of the Community-Based Environmental Monitoring Program

The flowchart illustrates that the program integrated educational, practical, evaluative, and sustainability-oriented components. Needs identification ensured that the intervention was based on local concerns, while the pre-test and post-test provided measurable evidence of knowledge development. The training and simulation stages were intended to strengthen participants' ability to recognize and record environmental indicators using a simple format. The reflective discussion and follow-up planning stages were included to encourage community ownership and continuity after the program ended.

Quantitative data from the pre-test and post-test were analyzed using descriptive statistics. The analysis included calculating the mean score of each indicator before and after the intervention, the absolute gain score, and the overall increase in participants' understanding. The difference between pre-test and post-test scores was interpreted as an indication of knowledge improvement after the educational and training activities. Because the number of participants was limited and the study was designed as a pilot community service program, inferential statistical testing was not applied. Data were tabulated and calculated using spreadsheet-based descriptive analysis to ensure transparency and replicability. The results were then presented in tables to show changes across the five measured indicators.

Qualitative data from observation, group discussion, and reflective evaluation were analyzed using a simple thematic analysis procedure. The implementation team reviewed field notes and observation results, identified recurring patterns, and grouped them into relevant themes. The main themes included local environmental concerns, participants' readiness to conduct simple monitoring, awareness of systematic reporting, and the sustainability of community participation.

These qualitative findings were used to support and interpret the quantitative results, particularly in explaining why certain indicators improved after the intervention. The integration of quantitative and qualitative data allowed the study to present both measurable evidence of knowledge improvement and contextual understanding of community capacity development.

The study followed ethical principles in community-based research and community service. Participation was voluntary, and all participants were informed about the purpose of the activity, the type of data collected, and the use of the results for academic publication and program development. Participants' identities were kept confidential, and the results were reported in aggregate form without disclosing personal information. The activity also emphasized that community observations should not be interpreted as formal evidence of pollution or environmental violation without further technical verification. Instead, the monitoring activity was positioned as an educational and participatory mechanism to help residents document early environmental indicators and communicate their concerns more systematically. Throughout the program, the implementation team respected local norms, community authority, and the principles of responsible academic engagement.

RESULTS AND DISCUSSION

Results

This section presents the results of the community-based environmental literacy and monitoring program conducted in Atuka Village. The findings are organized into five main parts: the initial condition of community understanding, the implementation of environmental literacy education, simple environmental monitoring training, improvement in participants' understanding based on pre-test and post-test results, and the follow-up plan for community-based monitoring.

Initial Condition of Community Understanding

The initial identification stage showed that most participants had direct experience in observing environmental changes around their residential area. During the preliminary discussion, participants mentioned several environmental concerns, including changes in water color at certain times, water turbidity, dust accumulation in several road points, noise, and visible changes in the surrounding environment. These responses indicate that the community already possessed local knowledge derived from daily experience. However, this knowledge was still mostly informal and had not been documented in a systematic manner. Participants generally had not been accustomed to recording the time of occurrence, location, weather conditions, visual characteristics of water, possible sources of disturbance, or supporting evidence such as photographs and location points.

The initial condition also revealed that participants still faced difficulties in distinguishing between natural environmental changes and changes that might be associated with human activities. This situation was particularly evident in discussions about water color, turbidity, dust, and noise. Participants were able to describe what they observed, but they were not yet familiar with how to organize these observations into structured information. Therefore, the program began by strengthening participants' basic understanding of environmental risks and introducing a simple mechanism for recording environmental findings. This stage became an important basis for designing the training activities and ensuring that the materials were relevant to the community's actual needs.

Implementation of Environmental Literacy Education

The environmental literacy session was conducted to improve participants' understanding of sustainable mining, environmental protection, community safety, land recovery, and socio-economic sustainability. The session emphasized that mining activities are not only related to mineral production but also to environmental responsibility and the protection of community living spaces. Participants were introduced to basic concepts of environmental impacts that may occur in mining-

related areas, including changes in water quality, dust, noise, land cover, and ecosystem conditions. The materials were delivered through interactive explanation, question-and-answer sessions, and discussion of environmental cases that were familiar to the participants. This approach helped participants connect the concepts presented in the session with their own observations in the village environment.

Reclamation and post-mining issues became one of the topics that attracted participants' attention. Participants found this topic easier to understand because it was directly related to visible changes in land and water conditions. The explanation was directed toward a practical understanding that land affected by mining activities should be managed, restored, and prepared to support ecological and social functions after mining activities end. In addition to reclamation, the session also introduced simple environmental indicators that can be observed by residents, such as water color, odor, turbidity, sediment, fish mortality, dust intensity, noise, and vegetation changes. Participants were also reminded that community observations should be recorded as early information and should not be used to make technical conclusions without further verification.



Figure 1. Documentation of the Opening Activity and Delivery of Mining Environmental Literacy Materials

Simple Environmental Monitoring Training

The simple environmental monitoring training was conducted through simulation and practice using a community-based observation sheet. Participants were divided into small groups and asked to identify sample environmental cases. Each group practiced recording basic information, including location, date, time, type of finding, weather condition, possible source of disturbance, visual evidence, and recommended follow-up action. The simulation showed that participants were able to complete the observation sheet when the format was simple, the terms were easy to understand, and the examples were close to their daily experience. The activity also encouraged participants to shift from oral reporting to more structured written documentation.

The monitoring sheet developed in this program was designed as a practical tool that could be used by residents without laboratory equipment. It did not require technical measurement but focused on observable indicators that could be documented consistently. The main components of the monitoring sheet are presented in Table 3.

Table 3. Community-Based Environmental Monitoring Sheet

Monitoring Component Information Recorded	
Location of finding	Village name, specific point, or simple coordinate.
Time of occurrence	Day, date, and time of observation.
Type of finding	Turbid water, dust, odor, noise, land change, or other findings.
Visual condition	Water color, odor, sediment, dust intensity, and vegetation condition.

Monitoring Component Information Recorded

Weather condition	Sunny, rainy, after rain, or cloudy.
Supporting evidence	Photograph, video, witness statement, or resident's note.
Follow-up action	Reported to village apparatus, relevant agency, or community forum.

The use of the monitoring sheet helped participants understand the importance of recording environmental findings in a consistent format. Participants learned that information such as location, time, weather condition, and visual evidence is important when communicating environmental concerns to relevant parties. The training also showed that simple instruments can support community participation when they are designed according to local needs and the practical capacity of residents. As a result, the monitoring sheet became one of the main outputs of the program.

Improvement in Participants' Understanding

The evaluation was conducted using pre-test and post-test scores from 10 participants who completed all stages of the program. The average pre-test score was 49.4, while the average post-test score increased to 79.8. This result shows an increase of 30.4 points after the environmental literacy education and simple monitoring training. The improvement indicates that the program helped participants understand mining-related environmental issues more clearly and practically. Since the evaluation involved 10 participants, the results are presented as the initial achievement of a pilot community empowerment program rather than as a generalization for all communities in Mimika.

The improvement occurred across all five indicators measured in the evaluation. The highest increase was found in the indicator of recording and reporting environmental findings, which improved by 34 points. The second highest increase was found in simple water quality monitoring, which improved by 33 points. These two indicators showed the strongest improvement because participants had previously lacked structured knowledge about how to document environmental findings and how to observe visual indicators of water quality. The detailed pre-test and post-test results are presented in Table 4.

Table 4. Evaluation Results of Participants' Understanding

Understanding Indicator	Average Pre-Test	Average Post-Test	Change	Description
Sustainable mining	53	81	Increased by 28 points	Improved
Environmental impacts of mining	55	82	Increased by 27 points	Improved
Reclamation and post-mining	50	80	Increased by 30 points	Improved
Simple water quality monitoring	45	78	Increased by 33 points	Improved
Recording and reporting findings	44	78	Increased by 34 points	Improved

Note. Scores were measured on a 0–100 scale. The number of evaluated participants was 10.

The results show that the program produced measurable improvement in participants' understanding of environmental literacy and basic monitoring practices. Before the program, participants were more familiar with describing environmental changes orally based on direct experience. After the program, they became more aware of the need to record findings by including location, time, type of finding, supporting evidence, and reporting channels. The increase in the water quality monitoring indicator also shows that practical examples helped participants recognize observable signs such as color, turbidity, odor, and sediment. Overall, the pre-test and post-test results demonstrate that the training strengthened participants' initial capacity to identify and document environmental issues in a more organized way.

Follow-Up Plan for Community-Based Monitoring

Another output of the program was the preparation of an initial follow-up plan for a community-based environmental monitoring group. This plan was developed through discussion with participants after the training and evaluation activities. The group was designed as a local forum that could conduct periodic observation, document environmental findings, and communicate information to village apparatus or other relevant parties. The follow-up plan focused on simple, realistic, and community-managed activities so that residents could continue the monitoring practice after the program ended. The planned activities are presented in Table 5.

Table 5. Follow-Up Plan of the Program

Follow-Up Plan	Activity Form	Person in Charge
Periodic water monitoring	Visual observation of water quality at selected points.	Community group
Dust and noise recording	Observation at certain times and locations.	Village youth
Documentation of environmental findings	Photographs, videos, and observation sheets.	Documentation team
Monthly community discussion	Discussion of findings and possible follow-up actions.	Community leaders
Communication with relevant parties	Submission of simple reports.	Village apparatus

The follow-up plan shows that the program produced not only increased understanding but also an initial structure for community action. Participants agreed that environmental observations need to be conducted periodically and documented in a simple format. The involvement of different community elements, such as youth, community leaders, documentation teams, and village apparatus, also indicates that the monitoring plan was designed as a shared responsibility. Although the plan was still at an initial stage, it provided a practical basis for continued community participation in environmental monitoring. This result strengthens the position of the program as an early model of community-based environmental capacity building in a mining-related area.

Discussion

The findings indicate that environmental literacy in mining-related communities needs to be developed through practical and contextual learning rather than through general awareness activities alone. The initial condition showed that participants already had experiential knowledge of environmental changes, such as water turbidity, dust, noise, and visible land changes, but this knowledge had not yet been organized into systematic documentation. Conceptually, this finding supports the view that local knowledge is a valuable starting point for community-based environmental governance when it is connected to structured observation and communication mechanisms. Previous studies have similarly argued that communities living close to environmental risks often possess situated knowledge, although this knowledge may remain weak in formal decision-making when it is not translated into communicable evidence (Brondízio et al., 2021; McEwen et al., 2022; Robins et al., 2022). In this study, the main problem was not the absence of community awareness, but the limited capacity to transform informal observations into organized environmental information. Therefore, the program extends the citizen science perspective by showing that environmental literacy should begin with the systematization of existing local experience.

The improvement in participants' understanding after the program demonstrates that interactive education can strengthen community capacity when the materials are closely related to residents' daily environmental realities. The increase from an average pre-test score of 49.4 to a post-test score of 79.8 suggests that participants were able to connect concepts of sustainable mining,

environmental risk, reclamation, water quality observation, and reporting mechanisms with concrete situations in their village. This finding supports the argument that learning in community empowerment programs becomes more effective when abstract environmental concepts are translated into observable indicators and practical tasks. It is consistent with studies emphasizing that citizen science and community-based monitoring can promote local learning, public awareness, and problem-solving capacity when participants are actively involved in the process (Bonney et al., 2023; Ballard et al., 2024; Taylor et al., 2024; Wright et al., 2021). However, this study differs from many citizen science initiatives that focus mainly on data collection because the intervention began with basic literacy and participatory training before asking residents to document environmental findings. This distinction is important because communities with limited access to scientific instruments require an empowerment pathway that starts from comprehension, observation, and simple documentation.

The strongest improvement was found in the indicator of recording and reporting environmental findings, which increased by 34 points. This result is meaningful because it shows that participants' main learning gain occurred in the ability to organize environmental observations into a structured reporting format. From a theoretical perspective, this supports the idea that community-based monitoring is not only about observing environmental conditions but also about creating a bridge between community experience and institutional communication. Previous studies have shown that citizen-generated environmental information becomes more influential when it is connected to reporting channels, community organizations, or decision-making processes (Cendejas et al., 2021; Dominguez-Rendón et al., 2024; Gupta et al., 2025; Nath & Kirschke, 2023; Perera et al., 2023; Sholihah & Gharesifard, 2025). The present study confirms this argument at a small community-service scale by showing that participants became more aware of the importance of recording location, time, visual evidence, weather conditions, and follow-up routes. Thus, the finding contributes to participatory monitoring literature by emphasizing that simple reporting literacy may be as important as environmental observation itself.

The increase in simple water quality monitoring also deserves critical attention because it reflects the relevance of observable environmental indicators for local communities. Participants improved their understanding of how water color, odor, turbidity, sediment, and other visual signs can be recorded as early information without making premature technical conclusions. This finding supports previous research showing that water-related citizen science is one of the most common and accessible forms of community environmental monitoring (Dominguez-Rendón et al., 2024; Shao & Bishop, 2025). It is also consistent with studies indicating that water monitoring can strengthen environmental awareness when residents understand both the possibilities and limitations of community observation (Cendejas et al., 2021; Gupta et al., 2025; Nath & Kirschke, 2023). Nevertheless, the present study takes a more cautious position by emphasizing that visual observation should not be treated as a replacement for laboratory testing. This is an important conceptual contribution because it positions community-based monitoring as an early-warning and communication mechanism, rather than as a substitute for formal environmental assessment.

The results also show that community-based monitoring in mining areas is closely related to transparency, trust, and environmental communication. In mining-affected contexts, environmental issues often become contested because community perceptions, corporate reports, and government assessments may not always operate within the same evidence framework. The use of a simple monitoring sheet helps reduce this gap by encouraging residents to distinguish between direct observation, suspected causes, supporting evidence, and the need for further verification. This finding aligns with the argument that participatory environmental monitoring can support more inclusive governance when local actors are not positioned merely as passive recipients of information (Albagli & Iwama, 2022; Skarlatidou et al., 2024; Tengö et al., 2021). It also extends studies on mining governance that highlight the importance of community participation, institutional trust, and accountable communication in extractive areas (Anindhita et al., 2024; Blesia et al., 2021;

Mokodompit et al., 2024). Therefore, the practical value of the program lies not only in knowledge improvement but also in strengthening the community's ability to communicate environmental concerns in a more evidence-informed manner.

The preparation of a follow-up plan for a community-based environmental monitoring group indicates that the program produced an initial form of social capacity, not merely individual learning outcomes. The proposed activities, including periodic water observation, dust and noise recording, documentation of findings, monthly community discussion, and communication with relevant parties, show that participants began to frame environmental monitoring as a shared community responsibility. This result supports the broader theory of participatory governance, which argues that sustainable environmental management requires interaction between citizens, local institutions, technical actors, and policy frameworks (Cooke et al., 2023; Willetts et al., 2022; Zerbian et al., 2024). Compared with studies that emphasize digital systems, advanced monitoring tools, or formal participatory committees, this study demonstrates that low-cost and low-technology approaches may be more suitable for early-stage capacity building in village communities (Danielsen et al., 2022; Guerrero & Sjöström, 2025; Walker et al., 2021). The difference may be explained by the local context, where the immediate need is not sophisticated data infrastructure but a simple mechanism that residents can understand, use, and sustain. This finding broadens the discussion of citizen science by highlighting the importance of appropriateness, accessibility, and community ownership in designing environmental monitoring interventions.

Despite these contributions, the findings should be interpreted within the limits of a small-scale community service program. The involvement of 10 participants makes the results useful as an initial indication of capacity improvement, but not as a basis for broad generalization across all mining-related communities in Mimika. In addition, the program did not include laboratory testing of water, soil, or air quality, so the monitoring outputs should be understood as educational documentation and early detection rather than technical evidence of pollution. This limitation is consistent with the distinction between community-based observation and formal environmental assessment in sustainable mining governance (Boullier & Henry, 2022; Jose et al., 2024; Li et al., 2026). However, the modest scale of the program is also part of its novelty because it addresses a gap in previous studies that tend to focus on larger citizen science projects, technological monitoring systems, or formal institutional arrangements (Akbar et al., 2021; Florkowska & Bryt-Nitarska, 2026; Miklian & Katsos, 2025). The study therefore contributes a replicable model for initiating environmental literacy and participatory monitoring in communities with limited technical resources, while also opening pathways for future collaboration with laboratories, local governments, mining companies, and universities.

CONCLUSIONS

This community service program in Atuka Village, Mimika Tengah District, Mimika Regency, Central Papua, demonstrates that environmental literacy in mining-related communities can be strengthened through a participatory approach and simple environmental monitoring training. The program improved participants' understanding of sustainable mining, environmental risks, reclamation and post-mining issues, simple water quality observation, and systematic recording and reporting of environmental findings. The evaluation of 10 participants showed a clear increase in understanding, with the average score rising from 49.4 in the pre-test to 79.8 in the post-test, indicating an improvement of 30.4 points. The main outputs of the program were a simple community-based environmental monitoring sheet and an initial follow-up plan for establishing a local environmental monitoring group. These findings suggest that small-scale, practical, and community-oriented training can serve as an initial model for empowering residents to participate in more transparent, organized, and sustainable environmental communication in mining areas. Future programs should include laboratory testing, simple monitoring tools, and periodic mentoring to strengthen the continuity and technical quality of community-based environmental monitoring.

AUTHOR CONTRIBUTION STATEMENT (11pt)

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AI DISCLOSURE STATEMENT

The authors used a language-support tool during the preparation of this manuscript for language refinement, clarity improvement, and structural editing. The authors thoroughly reviewed, revised, and approved the final version of the manuscript and take full responsibility for the accuracy, originality, and integrity of the published work.

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