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Improving Students' Knowledge of Biomonitoring through Service Learning in Higher Education Institution

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Biomonitoring, Knowledge, Service Learning.

Abstract. *Service learning in biomonitoring is urgent as it links science with community action to tackle river health issues.. This research aims to explore the application of service learning in enhancing students' knowledge and their ability to carry out river health biomonitoring projects. The study involved students in implementing the service learning curriculum through stages of planning, execution, reflection, and assessment. During the planning phase, students participated in developing the module. The results indicated that the biomonitoring module received a quality score of 3.8, with clarity of content and factual accuracy achieving the highest scores (4.0). The service learning program was conducted through the establishment of ECOFOREST groups, training sessions, and the application of action plans within the community. The effectiveness was measured using a one-group pretest-posttest design, which revealed a significant improvement in student understanding ($t(22) = 2.45$, $p < 0.05$). These findings confirm that service learning not only enhances student engagement in the community but also contributes to their technical competency development. This study addresses the gap in literature regarding service learning within more practical experiential learning frameworks in higher education.The result implies that there has been an increase of knowledge among the participants.*

Katakunci:
Biomonitoring, Pengetahuan, Service Learning.

Abstrak. Service learning dalam biomonitoring sangat urgen karena menghubungkan sains dengan aksi komunitas untuk mengatasi masalah kesehatan sungai. Penelitian ini bertujuan untuk mengeksplorasi penerapan service learning dalam meningkatkan pengetahuan dan siswa untuk melaksanakan proyek biomonitoring kesehatan sungai. Penelitian dilakukan dengan melibatkan mahasiswa untuk mengimplementasikan kurikulum service learing dalam tahap perencanaan, pelaksanaan, refleksi dan penilaian. Pada tahap perencanaan, mahasiswa dilibatkan dalam penyusunan modul. Hasilnya, modul biomonitoring memiliki kualitas baik dengan skor rata-rata 3.8, di mana aspek kejelasan materi dan akurasi fakta mendapatkan skor tertinggi (4.0). Program service learning dilaksanakan melalui pembentukan kelompok ECOFOREST, pelatihan, serta penerapan action plan di komunitas. Pengukuran efektivitas dilakukan dengan one-group pretest-

posttest design, yang hasilnya menunjukkan peningkatan signifikan dalam pemahaman mahasiswa ($t(22) = 2.45$, $p < 0.05$). Temuan ini mengonfirmasi bahwa service learning tidak hanya meningkatkan keterlibatan mahasiswa dalam komunitas tetapi juga berkontribusi pada peningkatan kompetensi teknis mereka. Studi ini mengisi kesenjangan literatur terkait service learning dalam pembelajaran berbasis pengalaman yang lebih aplikatif di perguruan tinggi. Hasil menunjukan ada peningkatan pengetahuan pada peserta.

1 Introduction

Environmental education is an essential component of higher education, providing training and preparing the future generation for a green society (Boca & Saraçlı, 2019). The ultimate goal is to create an impact on society by raising environmental awareness and promoting sustainable living (Tilbury, 2004). Various studies indicate that public engagement in social and environmental work is strongly supported by education and awareness-building (Agustang et al., 2023; Kaur & Mehndroo, 2022; Oe et al., 2022). While academic programs often emphasize theoretical knowledge, communities urgently require practical solutions and guidance to address environmental degradation in their surroundings. This gap highlights the urgency of service-oriented initiatives, where academic groups not only instill environmental awareness but also guide communities with scientifically grounded practices. Therefore, a knowledge-based environmental management program is necessary to ensure both societal relevance and adherence to academic criteria.

Service-learning projects in colleges and universities are beneficial across all disciplines (Juhász et al., 2021). In science and engineering, service learning is needed to introduce new knowledge and skills. For example, in the field of computer science, service learning is used to prepare communities for adopting new technologies (Kilkenny et al., 2022). In the social sciences, service learning is applied in social-justice education, helping students develop critical thinking skills and initiate social change (Mitchell, 2023). In other social science disciplines, service learning is used to integrate cultural studies with real-world, community-based learning (Cress et al., 2023; Scott, 2023). Furthermore, service

learning is also implemented in teacher education to provide pre-service teachers with exposure to schools and communities. As a result, service learning helps bridge theory and practice, enhances engagement, enables pre-service teachers to understand community needs, and equips them with the necessary skills to enter the workforce (Resch & Schrittesser, 2023).

Service learning is urgently needed to address environmental issues because it bridges the gap between academic knowledge and community-based needs (Boca & Saraçlı, 2019). While higher education provides students with theoretical understanding and technical skills, communities often face immediate challenges such as waste management, water scarcity, and ecosystem degradation that require practical and context-specific solutions. By engaging students directly in real-world environmental problems, service learning not only deepens their academic competencies but also ensures that scientific knowledge is translated into meaningful action for society. This dual impact—educating future leaders while simultaneously responding to urgent environmental concerns—underscores the relevance of service learning as a transformative approach to sustainability.

Unfortunately, in Indonesia, service learning is often associated with routine academic agendas that lack a strong scientific foundation, failing to implement curricula and learning tools that integrate both theory and practice. In higher education, service learning is more commonly known as (Community Service Program), which carries a credit load of 3-4 credits depending on the curriculum set by the university. Community Service Program is defined as “an intracurricular activity that integrates the implementation of the Tri Dharma of Higher Education with a method of providing learning and working experiences for students through community empowerment activities” (Aliyyah et al, 2021). This definition indicates that Community Service Program is part of the university curriculum and aims to provide students with experiential learning. However, this study argues that Community Service Program should not only serve as a learning experience but should also contribute to knowledge enhancement and be based on rigorous scientific principles.

In the field of environmental science, service learning programs that focus on environmental themes are still very limited. Theoretically, discussions on this topic have been widely documented in various scientific articles. However, research indicates that formal and informal education alone may not be sufficient for environmental protection. Therefore, community-based learning initiatives are necessary to enhance public knowledge and skills in environmental management to achieve sustainability. In this context, communities require knowledge reinforcement, skill development, and capacity building to manage their environments effectively (Hadi et al., 2023; Nasution, 2023). Globally, including in Europe, service-learning programs have faced challenges in effective consolidation, high-quality pedagogical implementation, and the integration of values, real-world problems, and approaches that uphold academic and scientific standards (Sotelino-Losada et al., 2021).

The environmental-themed service learning proposed in this paper introduces a novel integration of biomonitoring into community-oriented education. Biomonitoring, which assesses river health using biological indicators such as macroinvertebrates (Krisanti & Wardiatno, 2021; Sulastri & Sundari, 2023), has typically been confined to academic settings as part of the Biology Study Program at UIN Sunan Kalijaga. The present initiative extends this knowledge beyond the classroom by transforming it into a structured service-learning curriculum that enables students to apply scientific tools directly within community contexts. This approach is significant because it not only empowers students to translate theoretical understanding into practical contributions but also equips communities with scientifically grounded methods for environmental monitoring and decision-making. By positioning biomonitoring as both a pedagogical tool and a community service strategy, the program offers a distinct contribution to existing service-learning models, which often lack sustained integration of discipline-specific scientific practices.

The environmental-themed service learning proposed in this paper involves the implementation of a biomonitoring curriculum for community application. Biomonitoring is fundamentally an approach to monitoring river health using biological indicators, particularly

macroinvertebrates (Krisanti & Wardiatno, 2021; Sulastri & Sundari, 2023). Theoretically, this curriculum has already been introduced in the Biology Study Program at UIN Sunan Kalijaga and is now being adopted as a service-learning curriculum that encourages direct student contributions to communities. Furthermore, themed service-learning programs can address existing shortcomings in conventional service learning.

Service learning, particularly when integrated with hands-on scientific activities such as biomonitoring, offers a dual benefit: it equips students with practical technical skills while simultaneously addressing real-world ecological challenges. By involving students as active contributors and collaborators with local communities, this approach not only enhances their academic and professional competencies but also fosters a sense of environmental stewardship. Conducting research on such initiatives is crucial, as it provides empirical evidence of their effectiveness, informs best practices for environmental education, and supports the development of sustainable community-based conservation efforts.

Using the above framework, this study was conducted to document the service-learning activities carried out by university students in the watershed area of Yogyakarta, specifically in the Boyong River watershed (DAS Boyong), Sleman, Yogyakarta. This area is of particular importance as it serves as an urban buffer zone and a water source for the city of Yogyakarta, yet it faces numerous physical and biotic challenges (Sudiarti, 2006; Sulistiyowati et al, 2024). Consequently, local communities have a pressing need to monitor river quality despite their limited resources. At the same time, higher education institutions possess the human resources and knowledge to support communities in conducting simple and sustainable monitoring, particularly through biomonitoring (Sulistiyowati & Uyun, 2024). nstitutionally, the Boyong River community has established a river conservation group, KPLS, but its activities have not yet extended to monitoring. As a result, efforts to safeguard and oversee river health still rely heavily on the limited data provided by the government.

In response to these challenges, this paper aims to document the implementation of an environmental-themed service-learning curriculum (biomonitoring). This initiative begins with conducting service-learning activities and training student champions to implement the biomonitoring curriculum within communities. The novelty of this research lies in the fact that such an approach has rarely been applied in Indonesia, as service-learning activities have traditionally not been structured with clear methodologies and standardized frameworks.

2 Method

a. Service Learning in Biomonitoring

In general, this study adopts the service learning approach, defined as a method by which young people learn and develop through active participation in thoughtfully organized service and learning experiences (Felten & Clayton, 2011). This method engages students in learning and personal development through active participation in a structured service program. The approach was then renewed by several other authors, such as Salam et al. (2019) and Aramburuzabala & Cerrilo (2023), which stated that service learning should include several steps involving involves process of planning, action, observation, and reflection based on research to innovate and improve practice

The service-learning initiative in this study involves a group of students referred to as champions, who are primarily students from UIN Sunan Kalijaga, particularly from the Biology and Industrial Engineering Study Programs.

Several parties were actively involved in this research., such as the instuctors, who are also the main researchers, the students as champions, beneficiaries, and the Research and Community Development Unit of UIN Sunan Kalijaga (Error! Reference source not found.).

Table 1. The Parties Involved in Service Learning and Their Roles

Parties	Roles
Instructors/researchers	Designing the curriculum, trainings, and learning sources of biomonitoring and service learning
Students	As champions, students are responsible to identify the problems in the sociey. This problem was then formulated into action plans. Students executed the action plans with the help and collaboration with the instructors.
The community/beneficiaries	Working closely with the group of students to implement the action plans.
The Research and Community Development Unit of UIN Sunan Kalijaga	Providing support with the faculties and helping th intructors in designing the curriculum of student learning

The study focused on biomonitoring, which involves monitoring river water quality using macroinvertebrates as biological indicators. The technique employed macroinvertebrate sampling, followed by the calculation of the Biotilik Index (Anastasia et al., 2022; Rini, 2011). Biomonitoring using macroinvertebrates is widely recognized as an effective method for participatory river health assessment (Sulistiyowati & Uyun, 2024). The biomonitoring approach, utilizing the Biotilik Index, has been implemented in various rivers across Indonesia (Anastasia et al., 2022; Krisanti & Wardiatno, 2021; Sulastri & Sundari, 2023). Methodologically, it is well-accepted in the academic community and meets scientific rigor. Furthermore, several countries have adapted biomonitoring techniques to suit their local environmental conditions. Examples include Singscore in Singapore (Blakely et al., 2014) and AUSRIVAS (Banad et al., 2023)

b. The Planning Phase

First, during the planning phase, instructors developed the curriculum, training modules, and working methodology. Second, the student champions underwent training, formulated an action plan, and implemented the service-learning activities. Finally, an assessment was conducted to measure students' knowledge before executing the action plan in the field.

The module for learning has also been developed during the planning. The development of the module started with the formulation of the researchers' knowledge and experience related to biomonitoring into an initial draft. This knowledge was then structured into a blueprint module during the early phase. The module was tested by involving five Biology Study Program students, who practiced biomonitoring techniques as outlined in the module. Subsequently, the module was validated by experts in the Field of Ecology and Conservation from the Ecology Laboratory at UIN Sunan Kalijaga. After validation, the module was implemented in the biomonitoring-themed service learning program, involving student champions from UIN Sunan Kalijaga.

c. Action

The service-learning program was implemented through a series of structured activities designed to integrate academic knowledge with community engagement. Students were first trained in the principles and techniques of biomonitoring, including sampling methods, identification of macroinvertebrates, and interpretation of river health indices. Following training, students collaborated with local community members in designated river sites to conduct biomonitoring surveys. These activities involved joint field sampling, species identification, and data recording, supported by simplified tools and community-friendly modules. The action phase emphasized reciprocal learning, in which students applied their disciplinary knowledge while simultaneously facilitating community capacity-building in environmental monitoring.

d. Observation through Pretest and Post-test

The study employed a One-Group Pretest-Posttest Design, which is part of a quasi-experimental design. Although this design includes an intervention and measurements before and after, it does not have a control group for comparison. Therefore, it is challenging to determine whether observed changes are solely due to the intervention or influenced by other factors.

The research design structure is as follows:

Pretest (O_1) → Initial measurement before the intervention.

Intervention (X) → Implementation of the treatment/experiment.

Posttest (O_2) → Measurement after the intervention.

Schematically, this design is represented as follows:

O1 → X → O2

e. Data Analysis of Knowledge Aspect

The statistical test used in this study is the Paired Sample t-Test, which examines whether there is a significant difference between pre-test and post-test scores.

Hypotheses:

H_o (Null Hypothesis): There is no difference between pre-test and post-test scores ($\mu_1 = \mu_2$).

H_1 (Alternative Hypothesis): There is a difference between pre-test and post-test scores ($\mu_1 \neq \mu_2$).

The formula for the Paired Sample t-Test is:

$$t = \frac{\bar{D}}{sd/\sqrt{n}}$$

D=Mean difference in scores (post-test – pre-test).

Sd = Standard deviation of the difference in scores.

n = Number of participants.

3 Results

a. Development of the Biomonitoring Service Learning Module

In the module development process, the researchers were assisted by Biology Study Program students, who provided input on content coverage and accuracy. To assess the module, a Likert-scale questionnaire with scores ranging from 1 to 4 was used. The assessment results were then presented descriptively (**Error! Reference source not found.**).

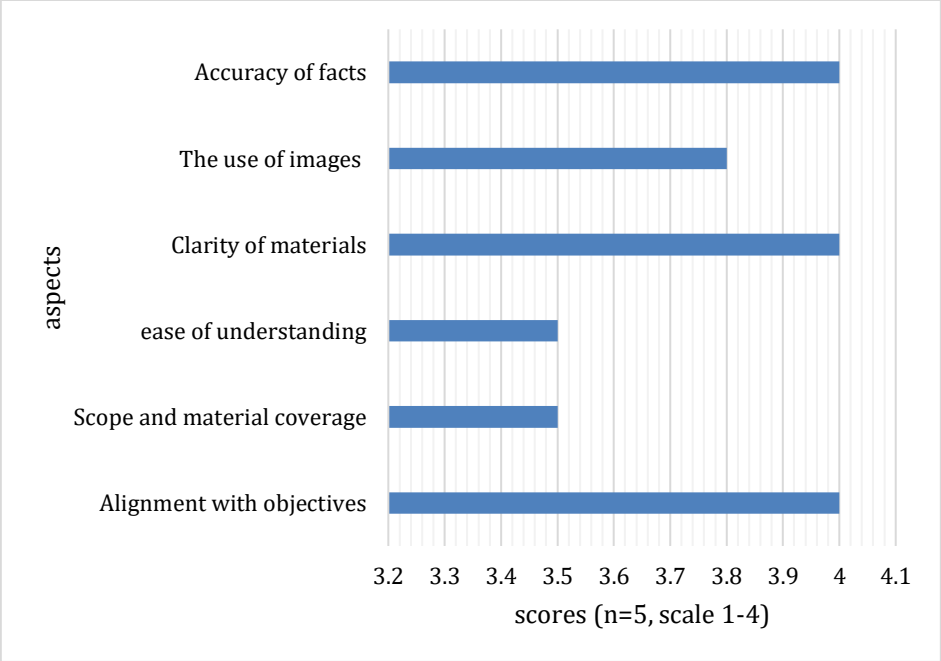


Figure 1. The Measurement of The Module's Technical Aspects was Conducted by Participants Using a Rating Scale of 1-4

The measurement results indicate that the developed module has high-quality content, with a score of 4. This aligns with the module development goal, which also received a score of 4. The clarity of the content received the highest score, 4, indicating that the structure and language used were effective in delivering the information. The use of images earned a score of 3.8, meaning that the visual illustrations were helpful but could still be improved to further support reader comprehension. The accuracy of the facts also scored highly, 4, indicating that the information presented has been verified and is trustworthy.

The lowest score was in the content coverage, which received a score of 3.5, suggesting that some topics may not have been fully addressed or need further elaboration. The ease of understanding also scored 3.5, implying that the material is fairly easy to understand, but certain sections may require simplification or additional clarification. On average, the module scored 3.8, categorizing it as good.

b. Implementation of Service Learning

The implementation of service learning begins with planning. Proper planning is essential because service learning involves many stakeholders, including students and community partners. This planning phase is also aimed at building strong relationships with the students as champions. During this phase, the identification of champions, the form of the project, and the technical pedagogical aspects that need to be explained to the students, including the modules to be used, are carried out. A main challenge during the planning stage is the lack of communication between the instructor and the community stakeholders who will be the beneficiaries. This difficulty is also reported by Swaminathan (2007) who stated that service learning planning at various education levels, including elementary and secondary, is a challenging effort. Community partners often fail to engage in all stages of service learning.

At the early stage of the program, the students arranged themselves in a group. The group called itself ECOFOREST, which stands for Empowering Community for Environmental Sustainability. The process of forming the organization was carried out in the form of a Focus Group Discussion (FGD) involving the researchers and the champions. Recruitment was done by inviting potential champions, resulting in volunteers who participated in the service learning program as part of the curriculum at the university. The material covered in the service learning outcomes includes environmental issues, water quality monitoring, and the adoption of water quality monitoring practices.

In addition to theoretical material, the content was delivered through community development training and capacity building using

the biomonitoring service learning module that had been developed. During the training, the champions were provided with basic instruments for engaging with community partners, identifying stakeholders, and communicating effectively with them. Next, the champions developed an action plan to be implemented with the community partners. Through service learning, the champions, who were university students, blended with the community in the process of community service. This not only provided knowledge benefits but also practical skills that they could use in daily water quality monitoring activities.

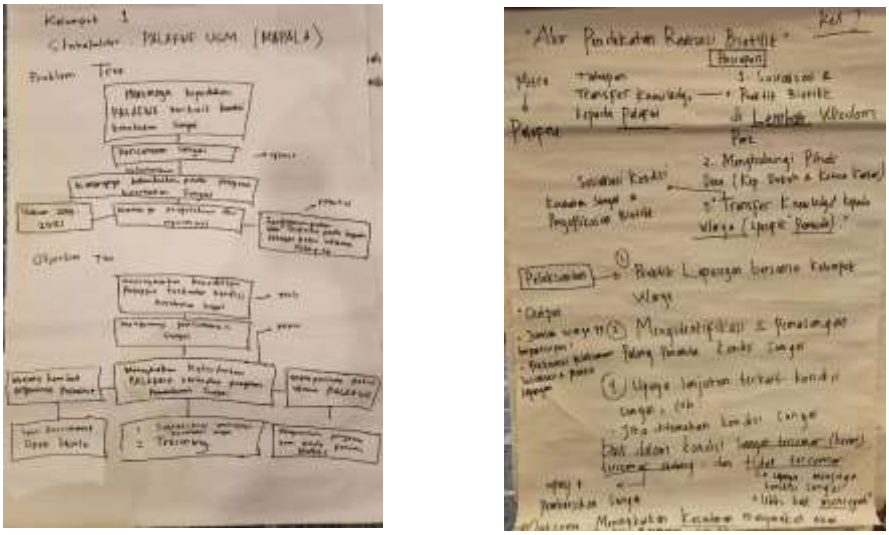
This program not only offered direct benefits in the form of increased student knowledge regarding biomonitoring material but also ensured the implementation of the action plans developed during service learning. The ultimate goal was to establish a water quality monitoring system through close collaboration between students and the community when students are deployed directly into the community.

The action plans in service learning were created by participants by analyzing the root problems using planning tools commonly used in project management. Several tools used included stakeholder analysis, problem tree, objective tree, and activities in the form of a Gantt chart. The objective tree developed by participants demonstrated their readiness to implement the program in the community. Action plans are vital components of successful service learning programs, providing structure, fostering engagement, and ensuring meaningful educational outcomes.

As educational institutions increasingly recognize the value of service learning in developing civic responsibility and practical skills among students, it is essential to address the challenges associated with action plan implementation. By investing in training for educators and establishing supportive policies, schools can enhance the effectiveness of their service learning initiatives and better prepare students for active participation in their communities.

This study encourages students to create action plans systematically, starting from creating problem trees and objective

trees. Planning tools like these are essential for guiding students through the process. Below is an example of an objective tree and action plan created by one of the groups. (**Error! Reference source not found.**).



a. Objective Tree b. Action Plans

Figure 2. Examples of Students' Work on Objective Tree and Action Plans

Figure 2 illustrates that students can identify stakeholders, root causes of problems, and the action plan to be implemented. More systematically, the following presents the analysis results conducted by the participants (Table 2). This table show that participants can identify problems, formulate program objectives, develop plans, and analyse potential stakeholders for collaboration. In this case, participants chose to collaborate with an environmental organization to execute the biomonitoring program. This organization was selected because it had previously implemented environmental-related programs and thus possessed relevant experience. Strengthening an existing organization was chosen due to its significant potential in carrying out biomonitoring.

Table 2. The Example of Action Plan Made by The Participants

Analysis of problems	Analysis of Objectives	Plans	Stakeholder
Inactive environmental organization	Revitalize the environmental organization	Organize activities for the environmental organization by assisting them in conducting open recruitment and an open house	Environmental Organization (PAHLAVE)
No environmental-related programs, such as river quality monitoring through biomonitoring	Increase environmental organization activities related to water quality monitoring	Conduct biomonitoring training Knowledge dissemination on biomonitoring	Community, PAHLAVE
Lack of environmental-focused activities	Develop institutional programs	Assist the environmental organization in designing environmental programs	PAHLAVE

At the end of the program, a structured discussion was conducted as a form of reflection with student champions to review the implementation of service learning and provide feedback on the program. As a crucial phase, reflection offers both instructors and students an opportunity to address issues that emerged during the service-learning process. The reflection process ensures that several aspects are evaluated, including the clarification of students' personal

values, reflection on the curriculum/course delivered, and reflection on the activities carried out during service learning (Whitney & Clayton, 2023). The reflection results indicate that service learning in the field of biomonitoring serves as an effective form of environmental education. In this regard, service learning can engage both the academic community and the wider society.

c. Measuring the Students' Knowledge Before and After the Program

Participants' knowledge was assessed using a set of questions designed to test their understanding of biomonitoring. The instrument used for this assessment consisted of 30 true-or-false questions covering fundamental environmental knowledge, biomonitoring concepts, and technical aspects of biomonitoring. Participants were given a pretest and posttest before engaging in service learning and receiving biomonitoring materials, following a one-group pretest-posttest design. A t-test was then conducted to analyze the pretest and posttest results (Table 3)

Table 3. T-Test in One Group Pretest-Posttest Design

	Score	*Score*
Mean	84.30 (posttest)	73.61 (pretest)
N	23.00	23.00
Pearson Correlation	0.46	
Df	22.00	
t Stat	2.45	
P(T<=t) one-tail	0.01	
t Critical one-tail	1.72	
P(T<=t) two-tail	0.02	

	Score	*Score*
t Critical two-tail	2.07	

The paired t-test results indicate a significant difference between the pretest and posttest scores, demonstrating an increase in biomonitoring knowledge after the service-learning program. The mean score of the posttest group (84.30) is higher than the pretest group (73.61), suggesting an improvement in knowledge. Additionally, the variance in the pretest group (553.16) is much larger than in the posttest group (90.22), indicating that initial knowledge levels varied widely among participants. Furthermore, the Pearson correlation coefficient (0.458) suggests a moderate relationship between the pretest and posttest scores. The statistical analysis also confirms the significance of the difference, as the t-statistic (2.449) exceeds the critical values for both one-tailed (1.717) and two-tailed (2.073) tests. These findings suggest that the service-learning program effectively enhanced participants' understanding of biomonitoring, highlighting its role as an impactful environmental education approach

4 Discussion

This study documents the development and implementation of a biomonitoring-themed service-learning program in higher education, showing how thematic modules can function as structured learning tools rather than merely guides for community service. Unlike previous thematic Community Service Program initiatives. The previos work includes research such aquaponics for rural tourism empowerment (Vitasurya et al., 2023), or SME branding modules (Putri & Candra, 2024), but the present work focuses on environmental biomonitoring, an area rarely addressed in Indonesian service-learning literature. The module here is not only an output of student work but also a standardized instructional resource designed for repeated application.

The findings highlight that the biomonitoring service-learning module was rated highly in clarity, factual accuracy, and content quality. More importantly, the program significantly improved students’ knowledge, as

shown by the pretest–posttest results. This aligns with earlier studies suggesting that well-designed service-learning programs can enhance both civic engagement and technical competency (Coelho & Menezes, 2021; Tawafak & Al Hinaai, 2024). In the environmental context, improved technical understanding is crucial because environmental literacy is strongly correlated with pro-environmental behaviors (Reddy, 2021).

Despite these successes, several challenges emerged, particularly regarding sustainability and institutional integration. As Coelho and Menezes (2021)note that long-term service-learning success depends not only on motivated students but also on faculty champions and supportive academic cultures. Common barriers include limited resources such as time, staff, and funding, as well as gaps in faculty training for integrating service-learning into existing curricula. In this study, strong institutional support from the university's community service unit mitigated some of these issues, enabling instructors to design and implement the curriculum with relative freedom.

Another key factor in program success was structured action planning. Students used stakeholder analysis, problem and objective trees, and Gantt charts to develop realistic, community-driven plans. Such structured tools not only improve project feasibility but also enhance students' project management skills—skills that are transferable beyond environmental monitoring. These approaches resonate with findings from Swaminathan (2007), who emphasized that sustained community engagement requires early and continuous collaboration with local partners.

Importantly, the measurable knowledge gains observed here address a gap in the service-learning literature. While numerous studies highlight community impact and student engagement, fewer measure domain-specific technical knowledge, especially in environmental monitoring. This research suggests that when service-learning is paired with a rigorously developed curriculum, it can simultaneously advance academic learning outcomes and community environmental capacity.

Beyond academic outcomes, the program also generated tbenefits for the local community. By involving residents directly in environmental

biomonitoring activities, the module provided communities with baseline data about water quality and ecosystem conditions that had not previously been systematically recorded. This information is valuable for raising local awareness of environmental risks and for supporting evidence-based decision making at the community level (Awaliyah et al., 2024). For instance, community leaders and residents can now use the monitoring results to inform local policies, advocate for environmental protection, or plan mitigation activities such as waste reduction and waterway rehabilitation.

The participatory nature of the program also helped foster a sense of ownership among community members. Rather than being passive recipients of student projects, residents were engaged in learning how to collect, interpret, and apply environmental data. Such empowerment is particularly impactful in rural or peri-urban areas, where institutional monitoring systems are often limited. By strengthening local capacity for environmental literacy, the program increases the likelihood that sustainable practices will continue beyond the students' involvement.

Moreover, the structured service-learning framework facilitated stronger university–community partnerships. The program demonstrated to local stakeholders that higher education institutions can serve not only as knowledge producers but also as long-term partners in addressing pressing environmental concerns. This relational impact is critical because it builds trust and lays the groundwork for ongoing collaborations, whether in future biomonitoring efforts or other community development initiatives. In this sense, the program contributes not only to immediate environmental improvements but also to the social capital that supports resilience and collective problem-solving.

Future work should explore longitudinal impacts, such as whether students and communities continue biomonitoring practices beyond the program period, and assess how integrating such modules into a wider range of disciplines might broaden their benefits. Additionally, scaling the program across multiple universities could help address the broader shortage of trained community partners in environmental health monitoring.

5 Conclusion

This study documents a thematic service learning program on biomonitoring, conducted at UIN Sunan Kalijaga. In this program, students played an active role as champions, forming the ECOFOREST group to implement biomonitoring activities in collaboration with the local community. Through training and hands-on implementation, the program not only enhanced students' academic understanding but also improved their social skills and ensured the sustainability of biomonitoring practices within the community. The statistical analysis of pre-test and post-test results indicated a significant increase in students' biomonitoring knowledge after participating in the service learning program ($t(22) = 2.45$, $p < 0.05$). This finding confirms the program's effectiveness in enhancing students' technical competencies. More broadly, this study addresses a gap in the literature regarding the effectiveness of service learning in improving technical understanding of environmental issues. Thus, this approach can serve as a learning model that not only fosters student engagement in the community but also strengthens their expertise in specialized scientific fields, particularly in environmental education.

6 Acknowledgment

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7 AI Statement

The authors acknowledge the use of AI assistance (ChatGPT, OpenAI) in this work, specifically for sentence structuring, English translation, and

language refinement. All ideas, interpretations, and final content remain the responsibility of the authors.

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