Jurnal Pendidikan Sains Indonesia
(Indonesian Journal of Science Education)
https://publications.usk.ac.id/index.php/jpsi

14(3), 960-975 (2026)
e-ISSN: 2615-840X p-ISSN: 2338-4379
https://doi.org/10.24815/jpsi.v14i3.2250

Implementation Green Chemistry Project: A Ways to Enhance Student's Environmental Literacy

Malikha Haula Karimah[1], Risa Rahmawati Sunarya[1*], Sari[1], Ida Farida[1], Riri Aisyah[1], Assyifa Junitasari[2,3]

[1]Department of Chemistry Education, UIN Sunan Gunung Djati, Bandung, Indonesia
[2]Department of Chemistry, UIN Sunan Gunung Djati, Bandung, Indonesia
[3]Graduate School of Natural Science and Technology, Kanazawa University, Japan

*Corresponding author's email: risarahmawatis@uinsgd.ac.id

Article History:
Received date: June 15 2026
Received in revised from: July 12 2026
Accepted date: July 24 2026
Available online: July 28 2026

Citation:
Karimah, M.H., Sunarya, R.R., Sari, Farida, I., Aisyah, R., & Junitasari, A. (2026). Implementation Green Chemistry Project: A Ways to Enhance Student's Environmental Literacy. Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education), 14(3), 960-975

Abstract. Rabbit urine contains beneficial nutrients for plants, and in this green chemistry project, its utilization in making liquid organic fertilizer (LOF) is demonstrated. This study aims to analyze the ability of students to design a project to make LOF with the addition of rabbit urine and analyze the improvement of environmental literacy. The research method used was pre-experimental with a one group pretest-posttest design. The research instruments used were student worksheet, pretest-posttest questions, and environmental care attitude questionnaire. The subjects of the study were 30 students in class X of Baiturrahman Ciparay Integrated High School. The data from the research was processed using Wilcoxon signed rank test statistics with a result of <0.001 which means that there is an increase in environmental literacy after learning. The results of the study showed that the ability of students to design a LOF project with the addition of rabbit urine as a whole was obtained at 81.75. The results of the analysis of environmental literacy improvement obtained an overall N-Gain value of 0.31 (medium), and based on aspects of content, context, and process of 0.31 (medium). The results obtained an average attitude score of 58.3 in the poor category. The results of the study show that the use of project-based worksheets that utilize rabbit urine in the manufacture of LOF effectively improves students' environmental literacy.
Keywords: Environmental literacy; PJBL; Liquid organic fertilizer, Rabbit urine

Introduction

Indonesia has become a participant in various international programs aimed at measuring students' science literacy. The Organisation for Economic Co-operation and Development (OECD) through the Programme for International Student Assessment (PISA) conducts a global assessment to test students' skills and knowledge in reading, mathematics, and science, so as to provide an overview of the education system at the international level. PISA provides reliable data to compare a country's science literacy, reading literacy, and math literacy levels with others, while understanding the weaknesses and strengths of the education system being implemented (Sujadi et al., 2022).

Science literacy in Indonesia according to the PISA ranking in 2022 is ranked 6th with 383 points from the average of OECD countries which obtained 476 points. This shows that Indonesia has relatively low literacy skills. According to the results of interviews with chemistry teachers at Baiturrahman Ciparay Integrated High School, in general, students are quite good at implementing environmental knowledge through projects at school. The shortcomings are in behavior or actions towards the environment in daily life. This is shown by habits such as the use of single-use plastic containers, then not being used to sorting waste by type. One of the teachers explained that in environmental literacy skills,

ecological knowledge and cognitive skills of the entire school community are quite good, it's just that the implementation in daily life is still not optimal (R. W. Pertiwi & Mustofa, 2025).

The skills of 21st century learners include literacy, competence, and character. Critical thinking, analysis, cooperation, and collaboration are essential components of problem-solving. This skill is related to science literacy. Environmental literacy is part of science literacy and has an important role in chemistry education.(Ate & Keremata, 2022; Hikmawati et al., 2021; Pursitasari, 2023).

Environmental literacy refers to a person's ability to understand, apply, and engage in various issues related to the environment (Mardiana et al., 2026). This ability includes an understanding of environmental concepts and principles, as well as the ability to interpret scientific information obtained. In its development, environmental literacy is also defined as awareness as well as real actions in maintaining and preserving the environment in a sustainable manner. Awareness and continuous action must certainly be accompanied by the ability to understand, understand, interpret, analyze, and use available information (Ulimaz, 2016; Meilina et al., 2024;Erlistiani et al., 2020; Ulimaz, 2021). According to North American Environmental Education (NAAEE) (2008) environmental literacy consists of four aspects which include ecological knowledge, cognitive skills, responsible actions towards the environment, and environmental care attitudes environmental literacy needs to be integrated into the curriculum in schools to help students develop a comprehensive understanding of the environment, its challenges, and the importance of sustainable practices through sustainable learning combined with the project (Jannah et al., 2026).

The PJBL model offers a more interactive approach and allows students to be active in solving environmental problems, which is in line with the goals of environmental education. In chemistry learning, activities are needed that can clarify the understanding of abstract material, namely by the practicum method. The importance of the practicum method in the PJBL model is reflected in research that shows that experimental activities not only improve academic understanding but also the practical abilities of students. The practicum method provides an opportunity for learners to experiment with natural materials, such as organic waste, in a real-world learning context (Mufidah et al., 2021; Putri & Rezania, 2024; Wicaksono et al., 2024).

Research shows that liquid organic fertilizer (LOF) can optimize the growth of plants, such as mustard greens, and provide better results than the use of chemical fertilizers. Practicum activities held in schools allow students to directly observe the fermentation process and its application, as well as measure its impact on plant growth. This can arouse students' interest in the study of science, especially in the fields of chemistry and agriculture. Through project learning, making green chemical products that utilize leftover organic materials can be a medium to improve one of the important skills developed in the 21st century, namely environmental literacy (Pariyanto et al., 2023).

Through the practicum of making LOF, students not only learn about the chemical context that occurs during the fermentation process but also about the importance of environmental responsibility in addition to students and innovations in producing products that are beneficial from waste. Students are directly involved and gain practical experience, will be better able to relate chemical concepts to real applications in daily life. Studies show that rabbit urine contains sufficiently high macro and micronutrients (especially N, P, K) compared to the urine of other farm animals, so it has the potential to be used as a base or additional source of LOF nutrients through fermentation with microbial starters such as EM-4 and the addition of molasses to improve the quality of N and C-organic. Frequently reported specific content includes N around 2–4%, P_2O_5 around 0.5–2.8%, and K_2O around 0.5–1.6%, although these figures vary depending on the rabbit's source, diet, and fermentation process. Preliminary test data on the content of macronutrients (nitrogen, phosphorus, potassium) in LOF made from banana tree waste and the addition of rabbit urine that had been made showed 0.59% nitrogen, 28.7420 ppm phosphorus, and 86.98

ppm potassium. These macronutrients meet the SNI standard for macronutrient content in LOF (Tampubolon et al., 2022).

The results of research conducted by Wicaksono et al. (2024) regarding the influence of the PjBL model on improving students' environmental literacy showed that the overall environmental literacy N-Gain value in the experimental class was 0.76 which was included in the high category, this proves that the PjBL model integrated with environmental themes is effective in improving students' environmental literacy (Wicaksono et al., 2024) . The results showed that there was an increase in students' critical thinking skills (CTS) and the indicators with the highest improvement were analyzing arguments (92.36%) and asking and answering questions (84.72%). The results of several studies show that the PJBL model can improve students' cognitive skills (Khoirunnisa et al., 2025; Delima et al., 2025; Nida et al., 2025). Furthermore, the research conducted by the one who analyzed the improvement of environmental literacy of high school students using a quasi-experimental method through a problem-based learning (PBL) and (Putri et al., 2024) the "about In, & for the environment" approach, the results of the study showed that the average posttest of the experimental class was 81% while the average of the control class was 68%. Several studies indicate that the implementation of project-based learning (PjBL) models with a green chemistry approach has been proven effective in enhancing environmental awareness and environmental literacy (Dionysios et al., 2021; Purba et al., 2026; Sunday et al., 2026; Supamongkolruek et al., 2026; Wang et al., 2026).

Based on the above background, no one has applied the process of making LOF with the addition of rabbit urine in chemistry learning activities with the aim of improving environmental literacy knowledge, which has become a skill in 21st-century learning.

Methods

The research method used was pre-experimental with a one group pretest-posttest design. This research was conducted in one experimental class without a control class. This design was chosen because of the limitations of forming comparison groups and considering homogeneous class conditions. This design makes it possible to determine learning by comparing the results of the pretest and posttest in the same group (Sugiyono, 2021).

This research consists of three stages, namely: Preparation stage, core stage, and closing. The preparation stage begins with analyzing KI, KD, syllabus, relevant journals, preliminary studies, preliminary tests for making LOF, and making instruments. The research instrument used was first validated by two lecturers who are experts in materials and media. The instruments are revised according to suggestions and input from validators so that the instruments used can be trusted to accurately measure the achievement of students' competencies (Purba et al., 2026). The implementation stage is carried out a learning process with project-based stages; analyzing problems, designing projects, executing projects, drafting/protozing products, measuring, assessing, and improving products, and finalizing and publishing products (Rahmat et al., 2023).

The final stage is focused on data processing, namely analyzing the value of project-based worksheets and data pretest-posttest as well as attitude questionnaires. The data were analyzed using Wilcoxon signed-rank test and also calculate the value N-Gain to find out the improvement of students' environmental literacy (Creswell & Clark, 2017). The research implementation time was carried out in February-June 2026, starting with the initial trial and the application of project-based worksheets to class X students at Baiturrahman Ciparay Integrated High School.

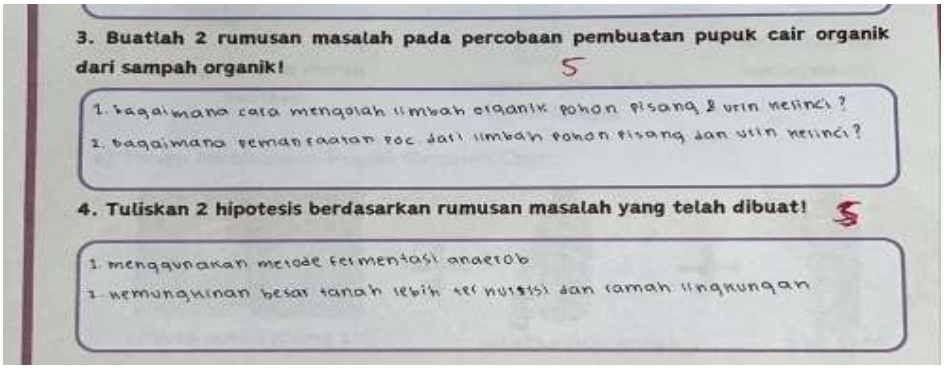
Results and Discussion

The results and discussion will be divided into two parts, namely the results of the analysis of the value of the project-based worksheet for making LOF with the addition of rabbit urine and the results of the analysis of improving the environmental literacy of students.

Project-Based Worksheet Value Analysis

PjBL activities consist of several stages, namely 1) analyzing problems, 2) designing projects, 3) executing projects, 4) drafting/prototyping products, 5) measuring, assessing, and improving products, and 6) finalizing and publishing products. Each stage is designed to encourage learners to be actively involved in the process of solving real-world problems, which is the basis for improving students' environmental literacy (Rahmat et al., 2023).

In this phase, students analyze problems in the form of discourses about soil pollution and the manufacture of LOF products through the fermentation process. Students are asked to determine the formulation of the problem, in question number 3, which can be seen in Figure 1 and then fill in the hypothesis or answer to the problem formulation from the discourse that has been read, which is stated in question number 4, can be seen in Figure 1. Based on the results of data analysis, the average score for phase 1 analyzing the problem obtained the highest score of 91.66 with the very good category. Research conducted by STEM-PjBL in improving environmental literacy shows that project-based learning is able to significantly improve students' environmental literacy skills, especially in the early phase of problem identification, making a positive contribution to improving environmental literacy (Pertiwi et al., 2019). An example of a student's answer in stage 1 can be seen in Figure 1.


3. Buatlah 2 rumusan masalah pada percobaan pembuatan pupuk cair organik dari sampah organik! 5

1. bagaimana cara mengolah limbah organik pohon pisang & urin kelinci ?
2. bagaimana pemanfaatan poc dari limbah pohon pisang dan urin kelinci?

4. Tuliskan 2 hipotesis berdasarkan rumusan masalah yang telah dibuat! 5

1. menggunakan metode fermentasi anaerob
2. kemungkinan besar tanah lebih subur dan ramah lingkungan

Figure 1. Example of student answers at the stage of analyzing problems

In the project design phase, students are infiltrated to rewrite tools and materials in the form of tables and procedures in the form of flow charts based on the pictures of the procedures presented, an example of a flow chart can be seen in Figure 2, in the image it can be seen that students write down the procedure for making LOF which includes the stage of preparing raw materials, the stage of making molasses and the stage of making LOF. In the project design phase, there are still many students who are not complete in writing tools and materials and still do not understand the term flowchart. The average score of the second phase was 75 with the Bai k category. This indicates that the project design stage is well done. This is in line with the findings (Masdiana et al., 2020). that the project design stage that is carried out well will contribute to increasing students' environmental awareness (Masdiana et al., 2020)n example of students' answers at the stage of implementing the project can be seen in Figure 2.

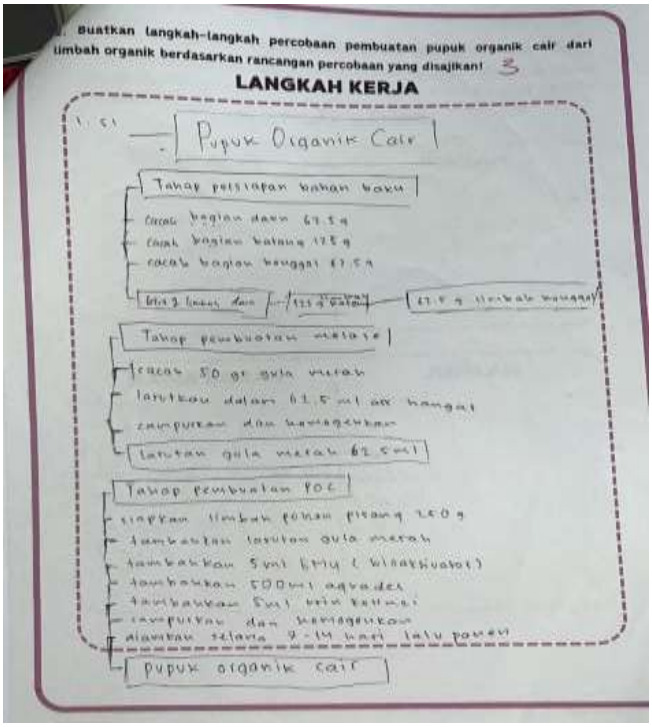


Figure 2. Sample answers for students in the project design stage

In the phase of implementing the project, students carried out experiments and wrote observations during the process of making LOF with the addition of rabbit urine. Writing student observation data in the form of a table that has been provided in a worksheet. In the third phase (implementing the project) obtained a score of 83.33 with a very good category. This is in line with Amaliyah's findings where the project progress stage that is carried out effectively contributes to improving children's ecoliteracy skills (Amaliyah et al., 2025). An example of students' answers at the stage of implementing the project can be seen in Figure 3.

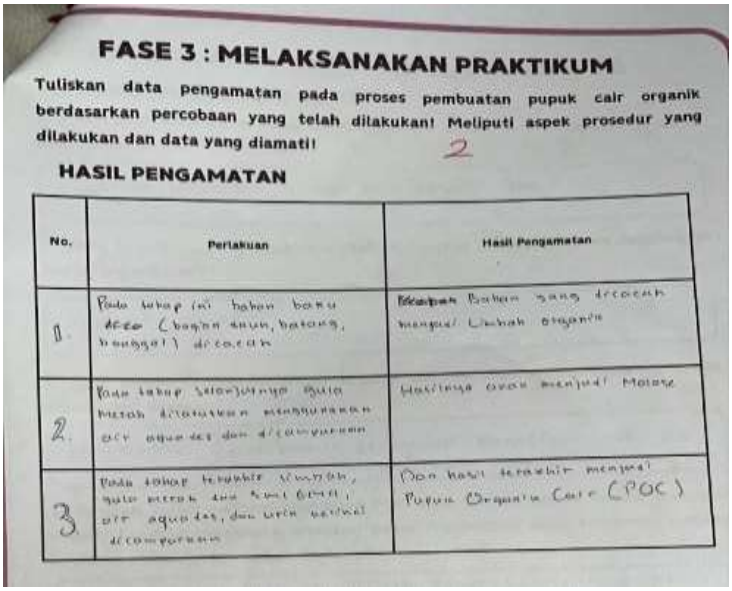
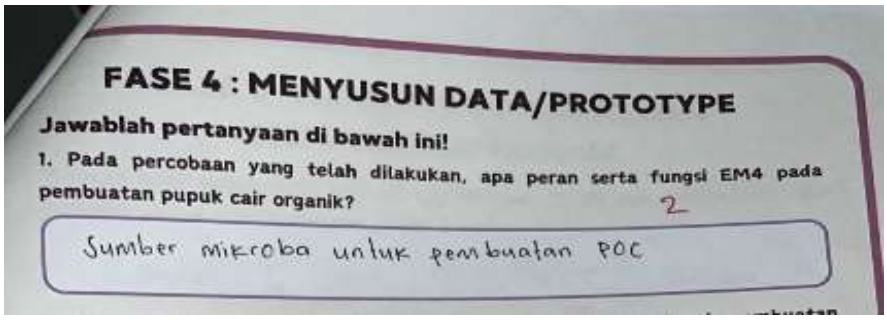


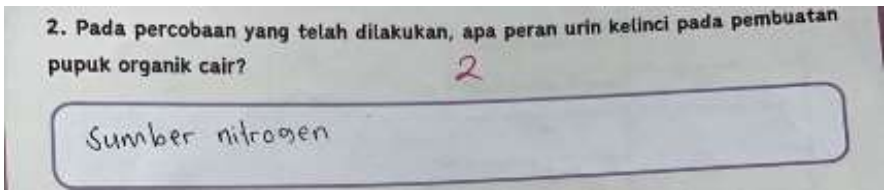
Figure 3. Example of student answers at the stage of implementing the project

In the phase of compiling product data/prototype, students answer the questions listed onthe worksheet. The questions amounted to five questions that will make students improve their understanding related to making LOF with the addition of rabbit urine (Salsabilla Khoirunnisa et al., 2025). When answering questions, students learn to connect new information with existing knowledge. Through the answers given, the researcher can assess the extent to which students understand the material or concepts that have been studied. In Figure 4 (a), question number 1 is a question about the function of effective microorganisms 4 (EM4) in the manufacture of LOF and the student's answer is "Source of microbes for the manufacture of LOF". In Figure 4 (b) is a question about the function of adding rabbit urine in making LOF and the student's answer is "nitrogen source". In Figure 4 (c) is a question about the chemical process used in the manufacture of LOF, the student's answer is "fermentation, the overhaul of complex compounds into simpler compounds by microorganisms". In Figure 4 (d) is a question about how environmental care actions are reflected through the LOF making project with the addition of rabbit urine, the student's answer is "We can use banana trees that have become waste and unused rabbit urine into LOF so that waste is not wasted". In Figure 4 (e) is a question about what other attitudes can help reduce waste problems, the students' answer is "processing into biogas".

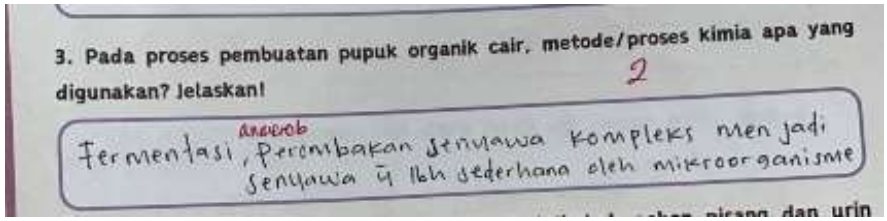
The average value of the phase of preparing product prototypes was 86.66 with the category of excellent, this is in line with the findings. that the implementation of STEM-PjBL which includes (Pertiwi et al., 2024) the discovery and application phases contributes significantly to increasing students' environmental literacy up to 16.94%, especially in the aspects of knowledge and cognitive skills in designing solutions to environmental problems examples of students' answers at the stage of implementing the project can seen in the Figure 4.



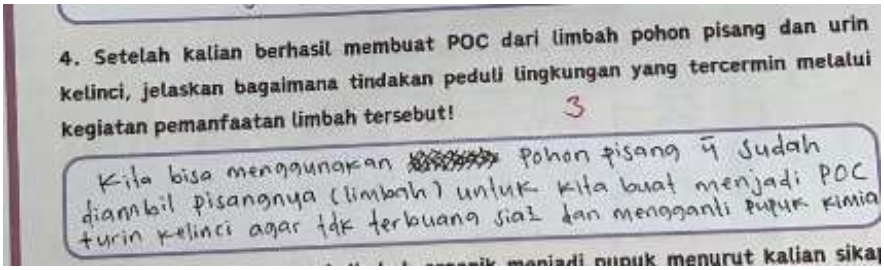
(a)



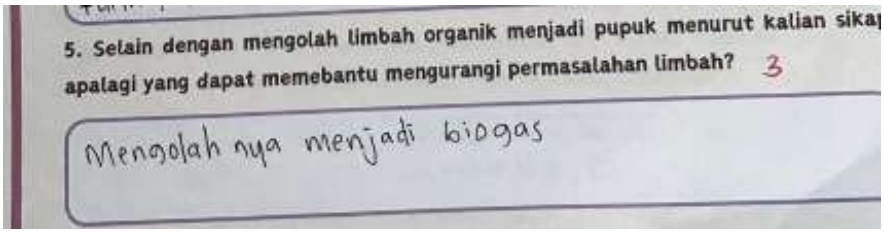
(b)



(c)



(d)

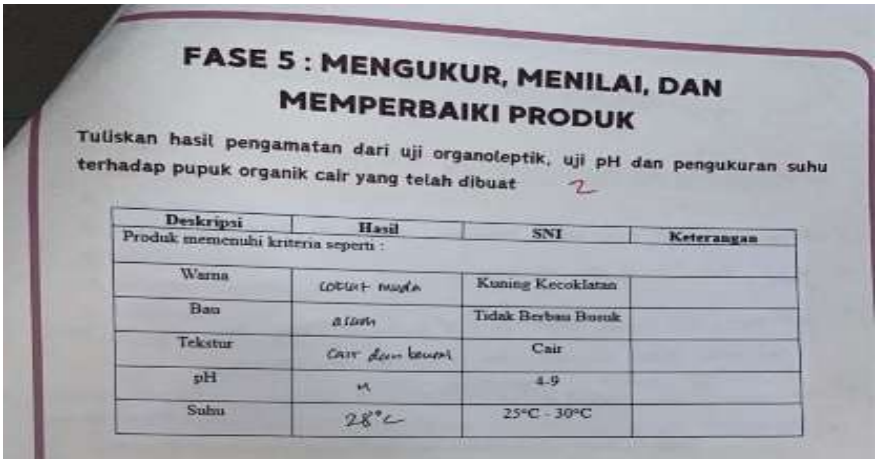


(e)

Figure 4. Sample answer of students at the data/prototype stage Products (a) Answer to question number 1 (b) Answer to question number 2 (c) Answer to question number 3 (d) Answer to question number 4 (e) Answer to question number 5

In the phase of measuring, assessing, and repairing the product, students conduct product assessment by testing LOF through organoleptic test, pH test, and temperature test. color, texture and odor. Figure 5 is a documentation of the activities of students who will conduct a LOF temperature test with a thermometer. Figure 6 (a) is an example of an assessment of the LOF that has been made. Figure 6 (b) is a question of analyzing the difference in macronutrient content of LOF without rabbit urine and LOF using rabbit urine. This phase obtained a score of 79.16 in the good category. This score shows that the reflection stage in PjBL has been implemented well. This is in line with the findings of (Setyowati et al., 2022) that the reflection stage in PjBL contributes to increasing students' critical thinking and creativity (Setyowati et al., 2022). An example of students' answers at the stage of implementing the project can be seen in Figure 5.

Figure 5. Student activities at the stage of measuring, assessing, and improving products

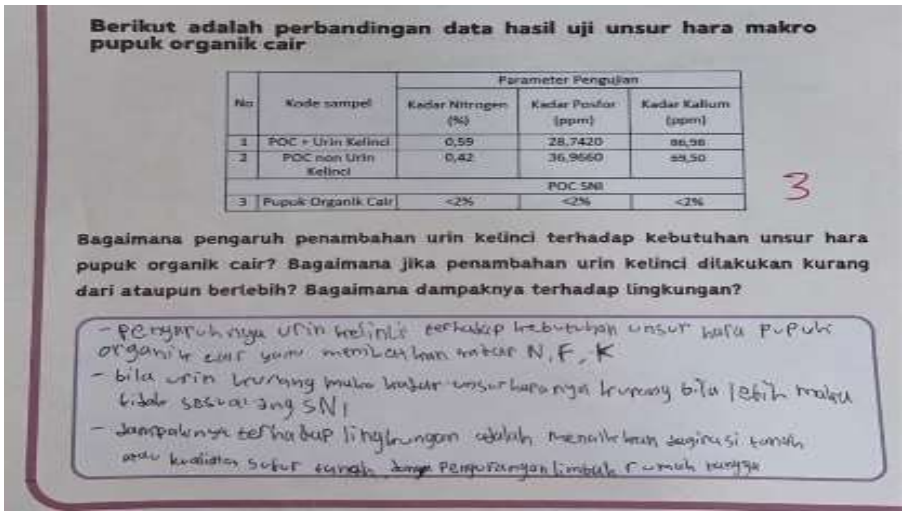


FASE 5 : MENGUKUR, MENILAI, DAN MEMPERBAIKI PRODUK

Tuliskan hasil pengamatan dari uji organoleptik, uji pH dan pengukuran suhu terhadap pupuk organik cair yang telah dibuat 2

Deskripsi	Hasil	SNI	Keterangan
Produk memenuhi kriteria seperti :			
Warna	coklat muda	Kuning Kecoklatan	
Bau	asam	Tidak Berbau Busuk	
Tekstur	cair dan bening	Cair	
pH	4	4-9	
Suhu	28°C	25°C - 30°C	

(a)



Berikut adalah perbandingan data hasil uji unsur hara makro pupuk organik cair

No	Kode sampel	Parameter Pengujian		
		Kadar Nitrogen (%)	Kadar Posfor (ppm)	Kadar Kalium (ppm)
1	POC + Urin Kelinci	0,59	28,7420	86,98
2	POC non Urin Kelinci	0,42	36,9660	89,50
		POC SNI		
3	Pupuk Organik Cair	<2%	<2%	<2%

3

Bagaimana pengaruh penambahan urin kelinci terhadap kebutuhan unsur hara pupuk organik cair? Bagaimana jika penambahan urin kelinci dilakukan kurang dari ataupun berlebih? Bagaimana dampaknya terhadap lingkungan?

- pengaruhnya urin kelinci terhadap kebutuhan unsur hara pupuk organik cair yaitu memberikan unsur N, F, K
- bila urin kurang maka kadar unsur hara nya kurang bila lebih maka tidak sesuai yang SNI
- dampaknya terhadap lingkungan adalah menaikkan fungsi tanah atau kualitas subur tanah dengan pengurangan limbah rumah tangga

(b)

Figure 6. Sample student answers in the stage of measuring, assessing, and improving products (a) Answer to question number 1 (b) Answer to question number 2

In the phase of finalization and publication of the product, students present the products that have been made and practicum reports in the form of posters and make conclusions from the projects that have been carried out. Documentation of poster presentation activities can be seen in Figure 7, example of poster can be seen in Figure 8 and example of conclusion answers can be seen in Figure 9. The presentation was carried out in groups and continued with a question and answer session to encourage students to discuss and equalize their perspectives. The finalization and publication phase of the product obtained a score of 74.16 in the good category. This is strengthened by the results of research on PjBL to improve (Delima et al., 2025) scientific writing which reports that the phase of writing scientific reports and presentation of project results is a crucial stage in integrating ecological literacy into students' final products. The achievement of 74.16 shows that the students have successfully passed the stage of writing and presenting the results of the project (Septriana et al., 2025).

Figure 7. Students present posters

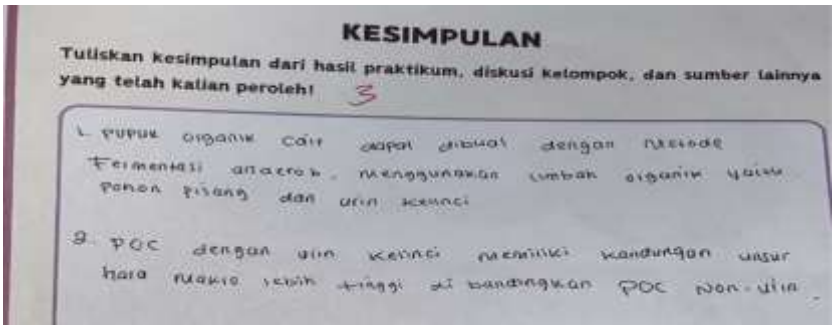


Figure 8. Conclusion answer at the product finalization stage

Figure 9. Example of a poster of students in the finalization and publication stage of the product

The overall scores of project-based worksheets can be seen in Table 1.

Table 1. Recapitulation of students' worksheet scores

Student worksheet scores at each learning stages						Quantity	Value
Project learning stages							
1	2	3	4	5	6		
21	6	3	15	6	30	81	100
19	5	2	12	5	25	68	84
20	5	3	15	5	18	66	81,4
19	4	2	13	4	23	65	80,2
19	4	3	12	5	23	66	81,4
77	18	10	52	19	89	265	340,2
91.66	75.00	83.33	86.66	79.16	74.16	81.8	81.75
Excellent	Good	Excellent	Excellent	Good	Good	Excellent	Excellent
Standard Deviation							
2.06	8.3	16.6	8.16	7.21	8.62	8.51	

Based on Table 1, the average percentage of students' worksheet scores is 81.75 in the very good category. This shows that students' activities in working on project-based learning worksheets are very well done. Based on the calculation results, the standard deviation from the total score of each group of students was ±8.51. This value indicates the degree of variation or deviation of each group's score against the average overall score, which is 81.75. In other words, the average difference in the score of each group from the average score is about 8.51 points. This standard deviation is relatively low on a 0–100 rating scale, which means that the scores between groups are relatively consistent and do not deviate significantly from each other. This indicates that the implementation of activities using project-based worksheets has succeeded in providing even learning outcomes. Although there was a slight difference in scores between groups, such as the group with the highest score of 93 and the lowest score of 81, the difference was still within reasonable limits. Therefore, it can be concluded that the learning activities carried out have run effectively and are able to have a relatively balanced positive impact on all groups of students (Sugiyono, 2021).

Analysis of Improving Environmental Literacy of Students

Students' environmental literacy skills are obtained from pretest and posttest questions. The pretest questions are done by students before the implementation of the worksheet, while the posttest questions are done after the implementation of the worksheet. The environmental literacy ability test for students consists of 15 multiple-choice questions. According to NAAEE (2011), this test refers to the aspect of environmental literacy which has three aspects, namely: 1) ecological knowledge, 2) cognitive skills, 3) responsible actions towards the environment. The average N-Gain value for each aspect can be seen in Table 2.

Table 2. N-Gain value of environmental literacy of students

Environmental literacy aspects	N-Gain			Average	Interpretation
	High	Mid	Low		
Environmental knowledge	-0.21	-0.01	-0.22	-0.15	Low
Environmental context	0.64	0.58	0.45	0.64	Medium
Action on the Environment	0.49	0.72	0.33	0.42	Medium
Average	0.3	0.34	0.27	0.31	Medium

Based on Table 2, the average N-Gain value for each indicator is 0.31, which falls into the medium category. These findings show that the use of project-based worksheets through the manufacture of LOF with the addition of rabbit urine makes a positive contribution to improving students' environmental literacy. However, this increase has not yet reached the high category, likely due to the research design used, i.e. a single-group experiment without a control group. This is in line with the findings, which show an increase in students' understanding in the medium category. This improvement was achieved through a single-group experimental design without a control group, thus limiting the ability to directly attribute the improvement to the given intervention (Wee et al., 2015).

The highest average N-Gain value was obtained in the second aspect, namely cognitive skills in analyzing the causes of environmental problems of 0.64. This achievement shows that the designed project-based learning activities successfully improve students' applied cognitive skills in a real-world context. The results obtained are in accordance with the research according to that knowledge about a balanced environment can influence a person's attitude and behavior (Kristyowati & Purwanto, 2019; Putra et al., 2024). Meanwhile, the lowest average N-Gain was found in the first aspect, namely ecological knowledge with a value of -0.15. This low achievement suggests that although the learning approaches used can improve learners' knowledge and skills, these non-conformities require more in-depth and sustained interventions. Low N-Gain values in the knowledge aspect often occur because project-based learning models often have several obstacles, one of which is the different levels of active involvement of students so that there is a potential for differences in understanding of the material in the project carried out by students (Aritonang et al., 2024).

N-Gain average score results Each environmental literacy indicator indicates that maximum test results are not always obtained by the high-achievement group. Likewise, the low-achieving group does not always get the minimum test results. This shows that the research conducted can help students in each achievement group to improve their environmental literacy skills. Average value of N-Gain Based on Table 2, the environmental literacy aspect is 0.31, which is included in the moderate interpretation. This shows that there has been a significant improvement in students' environmental literacy skills.

The results of environmental literacy research that are still in the medium category are relevant to the results of the research, which states that the level of environmental literacy of students is in the medium category. This is due to the use of new teaching models, methods, and materials that require adaptation to produce good learning. Meanwhile, according to , the factors that cause less-than-optimal learning outcomes are caused by the condition of students, the way teachers apply the learning model in the classroom, the selection of learning models, and the teacher's lack of ability. Based on this, to improve students' environmental literacy, it is necessary to develop and adjust learning

to have a positive effect on the environmental literacy aspect of students (Uyun & Suhartini, 2024) (Rohsulina et al., 2026). Meanwhile, the aspect of attitude of caring for the environment is measured through different instruments, namely in the form of a questionnaire containing 15 case statements that measure 3 dimensions of attitude, namely affective which is a dimension of feelings that refers to concern and empathy for the conditions of the surrounding environment, then the cognitive dimension, namely a person's understanding and awareness of environmental issues such as the impact of environmental pollution to understanding how to manage waste properly and conative dimensions (Marušić & Milica, 2020). The real embodiment or action of the affective and cognitive dimensions, for example related to daily habits related to the environment (Martiana et al., 2025). Each statement has 4 attitude response options in the form of multiple choices. The acquisition of the overall attitude value of the students can be seen in Table 3.

Table 3. Acquisition of attitude values

Attitude dimension	Value (%)	Interpretation
Affective	70	Pretty Good
Cognitive	60	Not Good
Conatif	40	Not Good
Average	58.3	Not Good

Based on Table 3, the average score of environmental care is 58.3, which is included in the range of poor categories. The assessment of the score of environmental care attitudes refers to the National Environmental Literacy Assessment (NELA) (2008), the affective dimension obtained the largest percentage of 70% which was included in the category of quite good then cognitive of 60% included in the category of poor and conative of 40% of the category of poor Overall, the average value of the attitude of caring for the environment of students was at a value of 58.3 which was included in the category of poor. The assessment of environmental care attitudes through PjBL can be low due to several factors such as the design and implementation of PjBL that is not optimal, structural barriers and student contexts such as diverse learning needs, workload, unsupportive school environment, then inadequate teacher roles and scaffolding, cultural/external such as social norms, community support, and access to direct experience with the environment, and the distance between attitudes and real behaviors that are not always in harmony, so that an increase in attitudes is not automatically followed by an increase in behavior measured as caring for the environment (López & Palacios, 2024).

Conclusion

Data analysis revealed that students' activities in project-based learning achieved an assessment of 81.75 in the very good category. The increase in students' environmental literacy in the aspect of environmental knowledge averaged -0.15, in the aspect of context towards the environment 0.64, and in the aspect of action towards the environment 0.42 so that an average N-Gain value of 0.31 was obtained in the medium category. The results obtained an average attitude score of 58.3 in the middle poor. Overall, it shows that the use of project-based worksheets utilizing rabbit urine in the manufacture of LOF effectively improves students' environmental literacy.

Acknowledgement

MHK acknowledges Department of Chemistry Education UIN Sunan Gunung Djati Bandung for funding the research publication and Laboratory of Chemistry Education for supporting the research.

References

Amaliyah, K.I., Hilmi, M.I., & Hasan, F. (2025). Project-Based Learning Based Environmental Wisdom Program (BILING) in Improving Children's Ecoliteracy Skills in the Banyuwangi Lare Sinau Community. Community Education Journal, 8(1), 123-132. https://doi.org/10.22460/commedu.v8i1.24864

Ate, D., & Keremata, L.Y. (2022). Analysis of Grade VIII Students' Ability to Solve Numeracy Literacy Problems. 6(1), 472-483. https://doi.org/10.31004/cendekia.v6i1.1041

Creswell, J.W., & Clark, V.P. (2017). Designing and Conducting Mixed Methods Research (3rd ed.). SAGE Publications.

Delima, D., Windayani, N., Aisyah, R., Sunarya, R.R., & Sukmawardani, Y. (2025). Application of Project Based Worksheet to Develop Students' Scientific Performance Through Making Hand Cream from Black Rice Kefir. Jurnal Pendidikan MIPA, 15(2), 752-764. https://doi.org/10.37630/jpm.v15i2.2853

Dionysios, K., Lemonia, A., & Katerina, S. (2021). Probing Greek Secondary School Students' Awareness of Green Chemistry Principles Infused in Context-Based Projects Related to Socio-Scientific Issues. International Journal of Science Education, 42(2), 298-313. https://doi.org/10.1080/09500693.2020.1867327

Erlistiani, M., Syachruroji, A., & Andriana, E. (2020). The application of the SSCS (Search, Solve, Create and Share) Learning Model to Students' Critical Thinking Skills. Jurnal Ilmiah Pendidikan Guru Sekolah Dasar, 13(2), 161-168. https://doi.org/10.33369/pgsd.13.2.161-168

Hikmawati, Sari, K.I.W., Maworksheetan, M., Andani, T.G., & Habibah, F.N. (2021). Development of Digital Literacy of Teachers and Students Through the Teaching Campus Program at SMPN 19 Mataram. Unram Journal of Community Service, 2(3), 83-88. https://doi.org/10.29303/ujcs.v2i3.71

Jannah, M., Nuraeni, E., Kusumastuti, M.N., Murae, F., & Rachman, I. (2026). Numeracy Literacy and Quantitative Literacy in Biology Education: A Systematic Literature Review. Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education), 14(2), 390-402. https://doi.org/10.24815/jpsi.v14i2.688

Kristyowati, R., & Purwanto, A. (2019). Learning Science Literacy Through Environmental Utilization. Jurnal Pendidikan dan Kebudayaan, 9(2). https://doi.org/10.24246/j.js.2019.v9.i2.p183-191

López, J.A.P., & Palacios, F.J.P. (2024). Effects of a Project-Based Learning Methodology on Environmental Awareness of Secondary School Students. International Journal of Instruction, 17(1), 1-22. https://doi.org/10.29333/iji.2024.1711a

Mardiana, E., Permana, I., Permanasari, A., Jaenudin, D., Matsumoto, T., & Rahman, I. (2026). Conservation Based E-Module Innovation to Improve Environmental Literacy in Biodiversity Learning. Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education), 14(1), 1-11. https://doi.org/10.24815/jpsi.v14i1.96

Martiana, A., Badriah, L., & Triyanto, S.A. (2025). Profile of Environmental Care Attitude of Grade XI High School Students in Tasikmalaya City. Biosintesa: Journal of Biology Education and Studies, 2(1), 20-24. https://journal.publinesia.com/index.php/biosintesa/article/view/137

Marušić & Milica. (2020). PaKSoM 2020 2nd Virtual International Conference Path to a Knowledge Society-Managing Risks and Innovation Proceedings. ALFATEC.

Masdiana, R., Kusnadi, K., & Munandar, A. (2020). Project-Based Learning to Enhance Student's Awareness Towards the Environment. Journal of Physics: Conference Series, 1521(4). https://doi.org/10.1088/1742-6596/1521/4/ 042005

Meilina, D., Hanafiah, N.A., Fatmawan, A.R., Hamzah, M.Z., Ulimaz, A., & Priyantoro, D.E. (2024). Effectiveness of Using the Mind Mapping Method to Increase Student Creativity in Learning. Innovative Education Journal, 6(1). https://doi.org/10.51278/aj.v6i1.1041

Mufidah, Z.R., Iswara, P.D., & Hermanto, F.Y. (2021). Developing Ecoliteracy and Ecopreneurship of Elementary School Students Through Thematic Learning Based on Project Based Learning (PjBL) Model. At-Thullab Jurnal Pendidikan Guru Madrasah Ibtidaiyah, 5(1), 75. https://doi.org/10.30736/atl.v5i1.509

Nida, K., Sunarya, R.R., Aisyah, R., & Dahriah, I. (2025). Project-Based Learning in Creating Edible Straws from Red Dragon Fruit Peel to Enhance Scientific Skills. Journal of Educational Chemistry (JEC), 7(1), 1-11. https://doi.org/10.21580/jec.2025.7.1.26563

Pariyanto, P., Santoso, S., Saroni, S., & Meilani, A. (2023). Utilization of Tofu Industrial Liquid Waste as Liquid Organic Fertilizer (LOF) on the Growth of Mustard Green Plants (*Brassica juncea* L.). Jurnal Riset dan Inovasi Pendidikan Sains, 2(2), 145-155. https://doi.org/10.36085/jrips.v2i2.5656

Pertiwi, R.W., & Mustofa. (2025). Analysis of The Impact of The Independent Curriculum on Students' Mathematical Literacy Abilities at MTS Mazro'atul Huda Wonorenggo Demak. Journal of Holistic Mathematics Education, 9(2), 180-212. https://doi.org/10.19166/johme.v9i2.10212

Pertiwi, P., Dony, N., & Mashuri, M.T. (2019). Development of Box Question Learning Media on Colloidal System Material at MA Siti Mariam Banjarmasin. Jurnal Pendidikan Kimia dan Ilmu Kimia, 2(2), 26-35. https://doi.org/10.31602/dl.v2i2.2385

Pertiwi, T.U., Oetomo, D., & Sugiharto, B. (2024). The effectiveness of STEM Project-Based Learning in Improving Students' Environmental Literacy Abilities. JPBI (Jurnal Pendidikan Biologi Indonesia), 10(2), 476-485. https://doi.org/10.22219/jpbi.v10i2.33562

Purba, L.S.L., Dasna, I.W., Munzil, M., & Wonorahardjo, S. (2026). Green Chemistry Learning: Project Based Integrated Local Wisdom to Cultivate Environmental Awareness and Student Learning Motivation. Multidisciplinary Science Journal, 8(9), 2026590. https://doi.org/10.31893/multiscience.2026590

Pursitasari. (2023). Critical Thinking & Ecoliteracy: Kecakapan Abad 21 untuk Menunjang Sustainable Development Goals. Ideas Publishing.

Putra, A.K., Oktavia, I.A., Vanti, Q., Kristanti, D., Sari, N.Y., Amrullah, M.A., & Nabilah, G.E. (2024). The Influence of Environment-Based Learning Projects on Students' Environmental Literacy. Jurnal Pendidikan dan Ilmu Pengetahuan, 24(3). https://doi.org/10.30651/didaktis.v24i3.24311

Putri, & Rezania. (2024). The Influence of Environment-Based Learning Projects on Students' Environmental Literacy. Jurnal Papeda Jurnal Publikasi Pendidikan Dasar, 6(2), 147-160. https://doi.org/10.36232/jurnalpendidikandasar.v6i2.5966

Rahmat, A., Zubaidi, M., & Mirnawati, M. (2023). Desain Pembelajaran Berbasis Proyek (1st ed.). Graha Ilmu.

Rohsulina, P., Deristani, A., Rahman, M.K., Sunarhadi, M.A., & Aji, B.K. (2026). Implementation of Project-Based Learning Based on Ecopedagogy as a Strategy to Strengthen the Profile of Pancasila Students in the Merdeka Curriculum. GeoEco, 12(1), 154. https://doi.org/10.20961/ge.v12i1.108618

Kuntum, S.K., Sunarya, R.R., & Yulia, S. (2025). The Implementation of Project-Based Worksheets to Develop Students' Scientific Performance Through Edible Film Production. Jurnal Penelitian Kimia dan Pendidikan Kimia, 8(1), 18-28. https://doi.org/https://doi.org/10.33059/katalis.v8i1.11836

Septriana, H., Suwandi, S., & Sumarwati. (2025). Project-Based Learning: Improving Scientific Writing Skills with the Integration of Ecological Literacy among Students. Educational Process International Journal, 15(1), 1-14. https://doi.org/10.22521/edupij.2025.15.123

Setyowati, L., Karmina, S., Sukmawan, S., & Razali, R. (2022). Green Project Work for Process Writing Amidst the Pandemic: Planning, Implementing, and Reflections. Jurnal Bahasa, Sastra, Seni, dan Pengajarannya, 50(2), 223-236. https://doi.org/10.17977/um015v50i22022p223

Sugiyono. (2021). Metode Penelitian Kuantitatif, Kualitatif, dan R&D (3rd ed.). Alfabeta.

Sujadi, I., Budiyono, B., Kurniawati, I., Wulandari, A.N., Andriatna, R., Puteri, H.A., & Nurmalitasari, A. (2022). Difficulties for Junior High School Students in Solving PISA-Like Math Problems. Edukasi: Jurnal Pendidikan, 20(2), 315-328. https://doi.org/10.31571/edukasi.v20i2.4781

Sunday, E.S., Samuel, H.S., Rickson, N.H., Musa, J., & Etim, E.E. (2026). Impact of Green Chemistry Education on Students' Learning and Environmental Awareness in Chemistry. Discover Education, 5(44), 1-24. https://doi.org/10.1007/s44217-025-01056-7

Supamongkolruek, C., Samiphak, S., Suphamongkonruek, S., Ch, O., Sala, A., & Phakdi, S. (2026). Fostering Environmental Literacy among High-School Students with Green Chemistry Using Case-based Learning. Journal of Education and Human Development Sciences, 10(1). https://doi.org/10.56825/jehds.2026.1016505

Tampubolon, K., Karim, A., Musri, M.A., Suhelmi, S., & Sitepu, E. (2022). Plant Fertility by Using Rabbit Urine with the Addition of Coconut Water and Pribiotic EM4 with Yakult Drink by Fermentation. Journal Liaison Academia and Society, 2(4), 63-83. https://doi.org/10.58939/j-las.v2i4.430

Ulimaz, A. (2016). Application of Guided Inquiry to the Cognitive Learning Outcomes of Grade VII A Students of SMPN 3 Tanjung in the Concept of Ecosystem. Jurnal Pendidikan dan Pembelajaran Konstruktivisme, 8(1), 96-100. https://doi.org/10.35457/konstruk.v8i1.8

Ulimaz, A. (2021). Student Response to Guided Inquiry-Based Practicum Modules in Online Learning Waste Treatment Technology Courses. Jurnal Humaniora Teknologi, 7(1), 21-26. https://doi.org/10.34128/jht.v7i1.98

Uyun, W., & Suhartini, S. (2024). Development E-Worksheet Using PjBL on Environmental Pollution to Enhance Environmental Literacy of Tenth Grade High School. Research and Development in Education, 4(2), 1485-1497. https://doi.org/10.22219/raden.v4i2.36936

Wang, J., Weng, Y., & Wanmei, L. (2026). Plant Secondary Metabolites in Action: A Green Chemistry Project-Based Module to Enhance Environmental Literacy in Middle School. Journal of Chemical Education, 103(5), 2785-2795. https://doi.org/10.1021/acs.jchemed.6c00074

Wee, L.K., Tan, K.K., Leong, K.T., & Tan, C. (2015). Using Tracker to Understand "Toss Up" and Free Fall Motion: A Case Study. Physics Education, 50, 436-442. https://doi.org/10.1088/0031-9120/50/4/436

Wicaksono, T.S., Ismawati, R., & Muhlisin, A. (2024). Implementation of Project-Based Learning Theme Blue My Sky is Healthy My Earth to Increase Environmental Literacy. Jurnal Pendidikan Sains dan Matematika, 12(1), 66-74. https://doi.org/10.23971/eds.v12i1.7114

Winda, R.A. (2024). Analysis of the Application of the PjBL Learning Model and Student Learning Concentration on Coordination System Materials at State High School 1 Pancur Batu. Jurnal Ilmiah Pendidikan Biologi, 10(2), 162-171. https://doi.org/10.22437/biodik.v10i2.33960