Jurnal Pendidikan MIPA
e-ISSN: 2685-5488 | p-ISSN: 1411-2531
URL: https://jpmipa.fkip.unila.ac.id/index.php/jpmipa
Jounal's DOI: http://doi.org/10.23960/jpmipa

Vol. 27, No. 2, 2026
Article ID: 1339
Pages: 1151-1167

The Impact of Environmentally Oriented Project-Based Learning on Students' Environmental and Science Literacy

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Received: 05 April 2026 *Accepted: 28 June 2026* *Published: 07 July 2026*

Abstract: Used cooking oil is a type of liquid waste that can pollute land and water. Processing used cooking oil requires knowledge and the application of scientific principles because it contains various chemical compounds formed during frying. Reusing it or processing it into other products requires an understanding of its chemical properties and the reactions that occur; therefore, education on handling used cooking oil waste requires appropriate learning methods. One appropriate learning method to implement is Project-Based Learning (PjBL). This research aimed to analyze the impact of implementing PjBL for Soap Production from vegetable oil waste on improving students' environmental and science literacy. The study was quasi-experimental and conducted using a pretest-posttest control group design. The sample included students from Muhammadiyah Lajoa Secondary School in Soppeng Regency, South Sulawesi, Indonesia. The total sample size was 76 students, divided into 38 in the comparison group and 38 in the experimental group. In line with the research findings, teaching the basics of ecology and natural science using PjBL yielded superior outcomes compared to traditional methods. The Mann-Whitney test revealed a significant difference in the normalized gain (N-gain) scores for knowledge of natural science and the environment ($p<0.001$) between the control and PjBL groups. Students using the PjBL method produced solid soap by following the correct steps of the soap-making process. A Wilcoxon signed-rank test showed a significant increase ($p<0.001$) after two stages of the soap-making cycle. Thus, the implementation of PjBL has a significant impact on improving students' literacy.

Keywords: project-based learning, environmental literacy, science literacy, used cooking oil, soap.

Article's DOI: https://doi.org/10.23960/jpmipa.v27i2.pp1151-1167

INTRODUCTION

A lack of environmental understanding, such as of the waste management system, often generates various environmental degradation problems arising from mismanagement and carelessness in the handling of waste, which cannot be addressed by one party; it is better to address them with the involvement of all the related stakeholders, especially those of early childhood environmental education institutions. Many challenges faced by teachers in handling of waste management include: student's low Environmental Literacy, difficulty in implementing student-centered learning, lack of student's activities in holding learning, limitation of teaching media, students' low analytical skill in identifying the issues related to waste and its impact to the environment and human life, and students' lack of awareness in making right decision in facing various human activities' potential environmental and health impacts. Teachers have difficulty handling waste management issues, connecting with children's experiences, or implementing experiential learning (Seprianingsih & Saputra, 2023; Debrah et al., 2021; Anuardo, 2022).

Waste management is a complex task that requires a scientific approach to prevent any damage to health and the environment. Thanks to science, recycling, energy, and the creative use of waste, innovations have been proposed to move towards a circular economy, sustainable ecosystems, and resilient economies (Aiguobarueghian et al., 2025; Pomoni et al., 2024). Domestic waste includes used cooking oil, which, if not disposed of correctly, can cause environmental and health hazards. By understanding the chemical reactions involved in transesterification (production of fatty acid methyl ester, FAME), saponification (production of amphiphilic compounds), and adsorption (purification), used cooking oil can be transformed into high-value-added products for preventing environmental pollution and for creating new economic opportunities, in line with a circular economy approach (Awoh et al., 2023).

Indonesia, the world's largest consumer of vegetable oil, produces an estimated 3 million tons of used vegetable oil per year. In urban areas, most used vegetable oil has been collected and used as a feedstock for biodiesel production, which is then exported to many countries (Mawardati et al., 2023; Sundoro & Putlia, 2021; Indonesian Ministry of Energy and Mineral Resources, 2020). However, in districts and rural areas, the collection and transportation of used vegetable oil have become a major problem due to high logistics costs. Much of the used vegetable oil was diverted for unauthorized dumping into canals and mixed with municipal solid waste, polluting the environment. The discharge of used vegetable oil into aquatic ecosystems elevates BOD and COD levels, contributing to significant environmental degradation. Furthermore, the surface lipid film weakens the penetration of solar radiation, thereby affecting photosynthesis and posing risks to aquatic organisms. The lipid film can also pose a contamination threat to groundwater (Awoh et al., 2023; Azme et al., 2023; Hosseinzadeh-Bandbafha et al., 2022; Ortner et al., 2016; Zamakhsyari et al., 2024).

Some riparian areas are disturbed by environmental pollution. In several spots around the Junior High School of Muhammadiyah Lajoa, Soppeng Regency, South Sulawesi, environmental pollution consists of anthropogenic solid and liquid waste, including used cooking oil and detergent, which are dumped directly onto the ground or into drains. Students and teachers at the Junior High School of Muhammadiyah Lajoa can address these local environmental issues by learning to manage school waste and by engaging in experiential learning about waste management. This approach is in line with the Kurikulum Merdeka guidelines contained in the Ministry of Education, Culture, Research, and Technology Decree No. 56 of 2022.

Although many efforts have been invested to educate students about waste management, the expected outcomes are yet to be achieved. Low student literacy on waste concepts and corresponding management materials remains a problem. A lack of understanding of fundamental waste principles, including classification and sorting, is evident. Raising awareness is no longer enough; students also need to be equipped with solutions and actions to tackle environmental issues.

PjBL (Project-Based Learning) is an instructional method that uses projects as a medium for learning. This approach requires students' competence in identifying, interpreting, and making decisions or drawing conclusions from data from various sources to achieve the learning process objectives. The approach encourages students to think critically and independently in facing various environmental problems. PjBL can be applied in various science study programs, including both natural and social humanities (Suryani, 2023; Wardani et al., 2023; Wirawan, 2022; Wiratman et al., 2023).

Research on scientific literacy related to used cooking oil conducted by Pratama et al. (2023) under title of "The Scientific Knowledge on Used Cooking Oil by the Students" revealed that most of the students carried out the scientific study in an unstandardized way, failed to connect the chemical knowledge and its implementation in the real situation of socio-environmental, and needed of a special treatment in the instructional approach in order to improve students' scientific literacy and to overcome academic emptiness. Meanwhile, our research aims to analyze the impact of implementing PjBL for soap production from waste vegetable oil on students' literacy and their ability to process used cooking oil into useful products. One product that can be developed from used cooking oil is soap. Beyond being a product needed in everyday life, soap production requires both theoretical and practical understanding. This PjBL is designed to explain the reuse of waste cooking oil from an ecological perspective. Also, this PjBL is intended to explain the experimental application of bleaching earth for the adsorption of contaminants and odors. Organic waste management using this method can protect the environment and offer alternatives and innovations in sustainable technology to minimize the use of synthetic chemicals (Azme et al., 2023; Octarya et al., 2025; Sarif et al., 2019; Sovia et al., 2020; Zahari, 2024). Therefore, after the learning process, it is expected that students' literacy and skills in utilizing waste will improve.

Project-Based Learning (PjBL) can be used to conduct real-world observational studies of environmental issues that require appropriate interventions tailored to learners' pedagogical skills and developmental stage. Environmental PBL aims to increase students' environmental awareness and their pro-environmental behavior. By identifying and handling sustainability issues at the ecosystem level, students can gain ecological awareness and eventually take action after they have acquired knowledge and prepared themselves to handle the problems (Aprilia, 2021; Cintang et al., 2018; Darojah et al., 2024; Mishra et al., 2023; Syahlan et al., 2023).

This study aimed to examine the implementation of the PjBL curriculum at SMP Muhammadiyah Lajoa, South Sulawesi, Indonesia. Students can apply what they have learned by chemically upcycling residual cooking oil into soap. To make the soap, they have to understand the saponification reaction by mixing some alkaline reagents and calculating the amount of reactants and products. This saponification reaction study not only requires critical thinking to solve problems but also encourages students to create new products based on their own ideas. Making soap from residual cooking oil is also a creative way to manage this waste. Science learning in real-life situations like this can make students more active in managing the environment and solving waste-related problems in their community.

SMP Muhammadiyah Lajoa, South Sulawesi, Indonesia, has been involved in a PjBL activity focused on the valuation of Used Cooking Oil (UCO) through saponification. In this PjBL activity, students are expected to have scientific literacy and numeracy to understand chemical reactions (alkali-lipid reactions) and to apply saponification stoichiometry to produce high-quality soap. The saponification reaction also challenged them to apply critical thinking skills to design experiments and refine the process to achieve better results. The products of the saponification reaction can be used as alternatives to eco-friendly products we use in our daily lives, which could otherwise harm the environment.

This study aims to describe and explain how the PjBL approach, using the UCO-to-soap model activities, can enhance students' environmental literacy, scientific literacy, and perception of science at SMP Muhammadiyah Lajoa. This research hypothesizes that using the PjBL method to process used cooking oil waste has a significant impact on improving student literacy at Muhammadiyah Lajoa Junior High School. The PjBL treatment group demonstrated higher environmental and science literacy, as well as soap production skills, compared to the control group.

METHOD

Participants

This study had limitations in the randomization process for forming the comparison and experimental groups, which could have introduced confounding variables related to student backgrounds. The limitations of quasi-experimental research were also reported by Fitriyani et al. (2025) and Rangkuti (2024). The total sample size was 76 students, divided into 38 students in the comparison group and 38 students in the experimental group.

In this study, the pretest and posttest instruments were not designed to measure mastery of specific curriculum material for a particular grade level, but rather to measure general knowledge relevant to all junior high school students. To ensure measurement equivalence, all instrument items were structured around competency indicators that were independent of specific learning materials taught at a single grade level. The combination of grades VII, VIII, and IX students was based on the research objective, which focused on evaluating the effectiveness of the PjBL learning intervention on junior high school students as a single population. The respondents' age range (approximately 12–15 years) is in the transition phase towards the formal operational stage according to Piaget's theory of cognitive development, so they can generally participate in the learning activities in this study (Cerovac & Keane, 2025 Rabindran & Madanagopal, 2020).

Research Design and Procedures

This study adopted a quasi-experimental design and employed a pretest-posttest control group design (Ali, 2023; Capili & Anastasi, 2024; Hastjarjo, 2019; Sigit et al., 2024). The research was conducted with students at Muhammadiyah Lajoa Junior High School in Soppeng Regency, South Sulawesi, Indonesia. Students who participated were divided into a treatment group that received instruction using PjBL and a comparison group that received instruction through a conventional method, such as one-way lectures and soap-making demonstrations, as illustrated in Table 1.

Table 1. Pretest-Posttest control group design

Group	Pretest	Treatment	Posttest
Treatment Class	Pretest of the treatment class	PjBL method applying	Posttest of the treatment class
Comparison Class	Pretest of the comparison class	conventional method applying	Posttest of the comparison class

PjBL was implemented with several structured stages. The project introduction stage presented the issues and initial reflections to introduce and build students' awareness of Sustainable Lifestyles as well as the concept of reusing various organic wastes. Next, the exploration and contextualization stage began by inviting students to examine the impacts of used cooking oil pollution, with a particular focus on the environmental damage it causes. To support this, the teacher utilized multimedia learning tools, including presentation slides and educational videos, accompanied by detailed explanations of the visual content. Students were subsequently assigned to observe the sources of used cooking oil generated in their residential environment, followed by class discussions to find solutions for safely disposing of, clarifying, and reusing it.

In the action stage, students clarified used cooking oil according to the method introduced in the previous stage and produced soap using a predetermined basic recipe (a soap formula with an oil phase consisting of 225 g of used cooking oil, 60 g of coconut oil, and 15 g of olive oil; and an aqueous phase containing 42.68 g of NaOH and 144 g of water). Students were also given the freedom to select the shape, color, and aroma of their preferred soap. The practice of soap making is carried out twice to improve skills and provide an opportunity to correct deficiencies encountered in the initial attempt.

Monitoring and Evaluation

The final stage of the PjBL implementation was evaluation, which comprehensively assessed students' knowledge and skills. First, the evaluation of environmental and science knowledge related to soap was conducted before and after PjBL administration using a questionnaire. The increase in student scores was calculated by normalizing pretest and posttest scores (Sarif et al., 2019). To achieve this, two sets of 30 multiple-choice questions were developed to assess environmental and scientific knowledge related to soap, and both sets were evaluated for validity and reliability. The validity test results showed that 22 items from the scientific knowledge test and 23 from the environmental knowledge test were valid, as evidenced by significant Pearson correlation coefficients ($p < 0.05$, $r_{count} > 0.361$). Meanwhile, the reliability test showed that the items have very high reliability, as evidenced by the Cronbach's alpha values of 0.909 for the science knowledge test and 0.934 for the environmental knowledge test. Cronbach's alpha values of around 0.70 or higher are desirable (Taber, 2018).

To determine the increase in environmental and science literacy, the N-Gain classification was used, as listed in Table 2.

Table 2. Categorization of N-Gain

Average of N-Gain Score	Categorization
1.00>N-Gain> 0.70	High level
0.70>N-Gain> 0.30	Medium level
0.30>N-Gain	Low level

(Source: Suryandari et al., 2018; Hake, 2002)

In addition to knowledge, the evaluation also assessed students' practical skills in making soap from used cooking oil using an assessment rubric. This rubric measured the discipline of implementing work safety procedures (first indicator), the accuracy of preparing the water phase or lye solution (second indicator), the accuracy of selecting and preparing the oil phase (third indicator), precise mixing of the solutions (fourth indicator), as well as adequate molding, insulating, curing, and cutting of products (fifth indicator). Each indicator included several sub-indicators, which were then scored on a Likert scale ranging from good (score 3), sufficient (score 2), poor (score 1), and not done (score 0). Each assessment item is being analyzed for its validity and reliability.

The data obtained from these processes were evaluated for normality using the Kolmogorov-Smirnov or Shapiro-Wilk test, Levene's test, and Wilcoxon or Mann-Whitney nonparametric tests in IBM SPSS 27. Finally, the PjBL stages concluded with an exhibition of student-created soap products made from used cooking oil. This exhibition was attended by students' parents, alumni, the Department of Education and Culture, Muhammadiyah Branch Leaders, and community leaders.

RESULT AND DISCUSSION

Evaluation of Students' Environmental and Science Knowledge

Following a dynamic focus group discussion, the school greenlit a Project-Based Learning (PBL) initiative titled "Transforming Used Cooking Oil into Soap." This project encompasses two Core Values and Concepts: Sustainable Lifestyles (used-oil purification) and

Engineering & Technology to Build Indonesia (soap-making). Students will learn scientific and numerical literacy while considering an eco-friendly approach to business and how to transform discarded items and their by-products into a value-added, marketable product for the local community.

The project is designed to explore the possibilities for reusing large amounts of organic waste in our daily lives and to encourage students to practice a Sustainable Lifestyle through the 5Rs. Unlike the more familiar 3R (Reduce, Reuse, Recycle) known to the public, this project aims to help students understand the 5R (Refuse, Reduce, Reuse, Recycle, and Rot) to adopt a sustainable lifestyle. To deter environmental aggression, the project will also explore composting and reducing waste (Mahartin, 2024; Nisa & Mutia, 2024).

This learning media is presented as an audiovisual and a description of the visual data, followed by an analytical note. After recognizing the harm and environmental disasters caused by non-biodegradable waste, students recorded the main points of the issue and then discussed them in groups. Emilie (2015) stated that the strategic use of learning media could foster environmental literacy and also suggest sustainable solutions to overcome environmental problems caused by human activities.

This paper explains the waste cooking oil purification project as a real-world context for teaching and learning science. This project was carried out using the Project-Based Learning (PjBL) approach, in which the entire activity was designed and implemented through a series of actions to achieve the project's goals (Milosopa, 2025; Syahlan et al., 2023). At the beginning of the activities, students were divided into groups and created a scientific poster on the environmental impact of waste cooking oil, covering aspects such as toxicity, treatment, and reuse. The poster was displayed during the gallery walk for discussion, idea sharing, and critical thinking about other groups' work. Then, the plenary discussion on solutions for the management of waste cooking oil disposal, treatment, and reuse followed. The ideas could be improved by the instructor as a scaffolder in the discussion and could ultimately be finalized through an experimental method for used-oil reuse. Although educational interventions to enhance environmental literacy and ecological responsibility regarding waste management exist, it is the teacher who can act as a catalyst for change (Emilie, 2015).

The wasted vegetable oil was collected from private sources and used for production. After collection, the waste vegetable oil was purified using adsorbents in powder or granular form (e.g., activated carbon, bleaching earth) to obtain the purified oil. These triglycerides in oil would serve as the base material for producing solid soap by the cold-process method. Some ideas and concepts on the basics of the saponification process, the calculation of materials needed using soap calculators, the selection of raw materials for soap production, and laboratory safety procedures were studied before entering the production stage.

Figure 1 and 2 shows the learning performance of both the experimental and comparison groups on the posttest of environmental and science knowledge.

Generally, the treatment group showed a better learning performance than the comparison group. The results showed that the PjBL model was more effective at yielding better knowledge acquisition in both environmental and science content than the conventional approach. This is evident in the scatterplot of environmental knowledge (Figure 1). The graph of the pretest results (x-axis) and the posttest results (y-axis) shows points with a positive trend, shifting toward the upper-right corner. The greater improvement in environmental knowledge in the PjBL group is

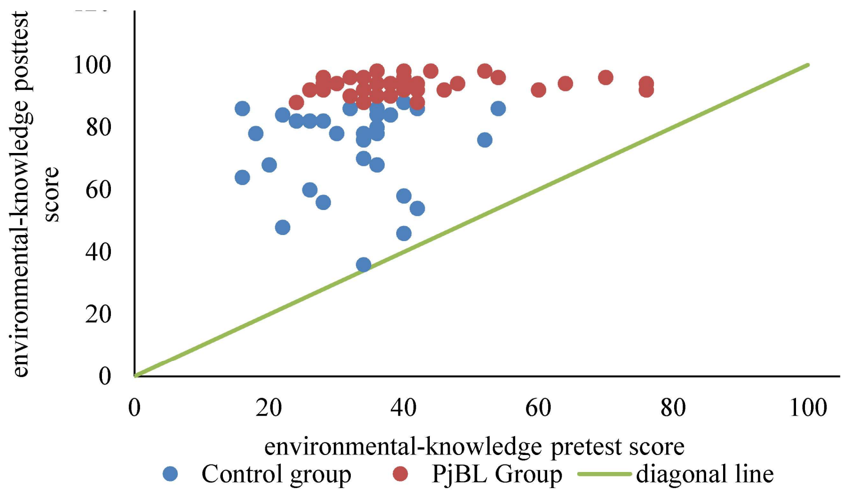

Figure 1. Scatter plot of students' knowledge about the environment, before and after the implementation of PjBL

indicated by the data points in the PjBL group being far above the diagonal line. Meanwhile, the control group distribution plots much closer to this diagonal line. The distribution of points clustered between 80 and 95 on the Y-axis indicates that PjBL produced nearly uniform posttest results in environmental knowledge, despite differences in pretest results. A similar

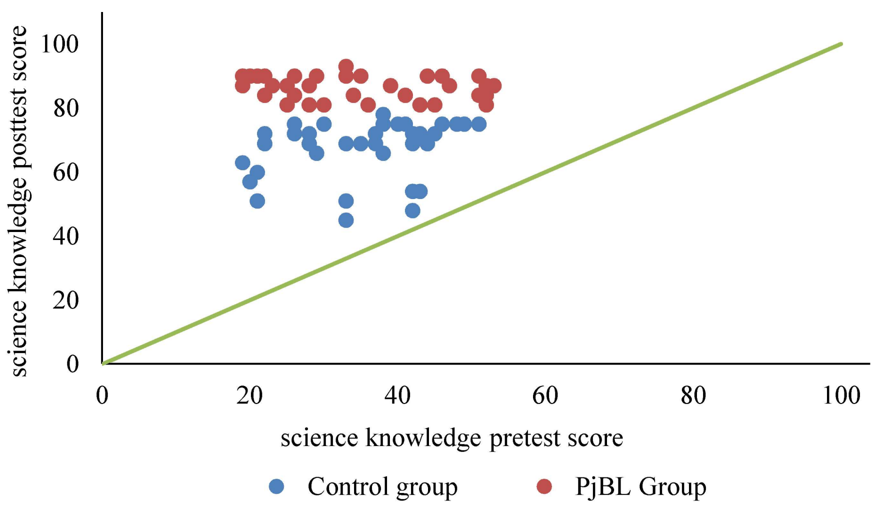

Figure 2. Scatter plot of students' knowledge about science, before and after the implementation of PjBL

pattern was observed in PjBL learning outcomes for students' science knowledge, specifically regarding soap (Figure 2).

The increase in environmental and science literacy is demonstrated by the Normalized Gain (N-Gain) shown in Figure 3 below.

As shown in Figure 3, the experimental (PjBL) group achieved a high increase in science knowledge (0.79; 79%) and environmental knowledge (0.89; 89%), while the control group showed moderate increases for both types of knowledge (0.49; 49% for science knowledge and 0.63; 63% for environmental knowledge).

A homogeneity of variances test was conducted to compare the variances of the pretest results between the two groups. The

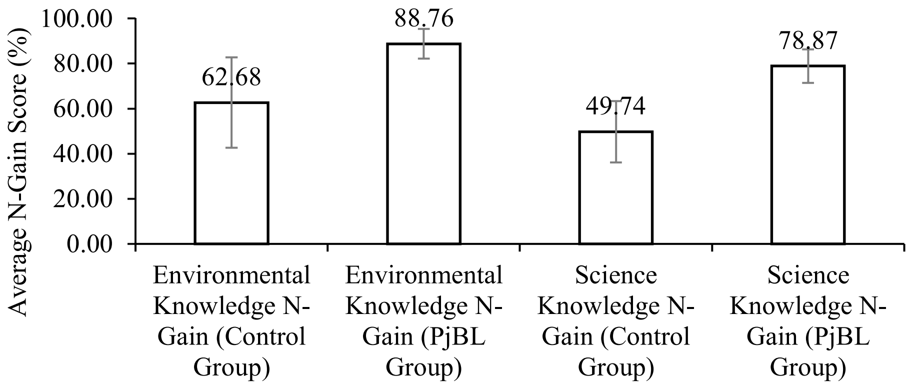

Figure 3. Histogram of n-gain score of environmental and science knowledge

results of Levene's test for the homogeneity of variances, shown in Table 3, indicated that the p-values were > 0.05, namely, p = 0.256 for environmental knowledge and p = 0.142 for science knowledge. It meant there were no significant differences in the variances of the two groups before treatment. Therefore, the differences after treatment really stemmed from the treatment given.

The non-parametric Mann-Whitney test was used to analyze the difference in N-Gain between the PjBL and control groups for both environmental knowledge and science knowledge. This test was chosen because the parametric test's assumptions were not met. After all, the data were not normally distributed based on the Kolmogorov-Smirnov test ($D(76) = 0.196$, *$p < 0.001$ for environmental knowledge N-Gain), and the data were not homogeneous based on Levene's test ($p < 0.001$ for environmental knowledge N-Gain and $p = 0.021$* for science knowledge N-Gain). The Mann-Whitney analysis results ($p<0.001$) indicated N-Gain score environment and science knowledge in the treatment group was statistically higher than that of the comparison group.

Table 3. Test of differences in average pretest scores, n-gain of environmental and science knowledge between control and experimental groups

Average score	Class	Statistical test	Significance	Description
Environmental Knowledge Pretest	Control and experimental groups	Levene's Homogeneity test	p=0.256	The initial abilities of the comparison and treatment groups were the same before the study.
Science Knowledge Pretest	Control and experimental groups	Levene's Homogeneity test	p=0.142	
N-Gain Environmental Knowledge	Control and experimental groups	Test of Normality with the Kolmogorov-Smirnov Test	D (76) = 0.196 p<0.001	N-Gain of environmental knowledge in the comparison and treatment groups was not normally distributed.
		Levene's Homogeneity test	p<0.001	N-Gain environmental knowledge in the comparison and treatment groups was not the same.
		Non-parametric test Mann-Whitney	p<0.001	N-Gain environmental knowledge score of the treatment group was

				statistically higher than that of the comparison group.
N-Gain Science Knowledge	Control and experimental groups	Test of Normality with the Kolmogorov-Smirnov Test	D (76) = 0.091 p=0.193	N-Gain of science knowledge in the comparison and treatment groups was normally distributed.
		Levene's Homogeneity test	p=0.021	N-Gain of science knowledge in the comparison and treatment groups was not the same.
		Mann-Whitney non-parametric test	p<0.001	The N-Gain score for science knowledge in the treatment group was statistically higher than that of the comparison group.
Waste cooking oil, soap-making skill score	Stage-1 and Stage-2 in the experimental groups	Wilcoxon non-parametric test	p<0.001	The soap-making skill scores at the second stage were significantly higher than at the first stage.

Both the distribution of student scores shown in the scatterplot (Figures 1 and 2) and the statistical test results (Table 3) indicate that the PjBL method significantly improved students' literacy skills. The PjBL method is very useful in fostering scientific understanding, especially in complex chemical reactions. Using PjBL yielded better pedagogical outcomes than traditional methods for teaching saponification. The process of making soap from recycled cooking oils involves complex chemical reactions that require an understanding of many specialized concepts that are difficult to cover in a didactic setting with minimal hands-on learning experiences.

The PjBL is experiential and enables in-depth learning of a range of scientific concepts through the investigation of real-world problems in the classroom. One project that can be done to pursue experiential learning about elements, compounds/mixtures is the synthesis of soap from waste cooking oil. This project will also provide an opportunity for students to apply qualitative pH testing with litmus paper and universal indicators to the reactants and products. The saponification reaction is an excellent example of a phase change from liquid to solid and a chemical change. Prior knowledge of the highly exothermic dissolution of NaOH solution is essential, as is a proper understanding of laboratory safety procedures and handling of dangerous and caustic substances.

Evaluation of Students' Skills in Making Used Cooking Oil Soap

The preparation of the aqueous phase, the incorporation of the lipid phase, and the homogenization of the soap paste were conducted in accordance with established protocols (Octarya, 2025; Sukeksi et al., 2021). This activity was conducted twice to help students correct deficiencies identified in the first phase and to support them in problem-solving, namely understanding the correct method for mixing and pouring the soap solution, how long to stir the solution, and when to pour it into the mold. Soap-making was not among the skills taught to the control group, which received conventional instruction. In the control group, the teacher made the soap to demonstrate to the students, while some students made it as part of their activities during the session.

The rubric for assessing students' skills in making soap from used cooking oil was developed around several key aspects of soapmaking. The aspects assessed included discipline in implementing work safety procedures; the accuracy of preparing the water phase (alkali solution) and the oil phase; the accuracy of mixing the two phases; and the molding, curing, and cutting processes. However, several assessment items were found to be invalid because all students showed consistent results across these sub-indicators. For example, the rubric for assessing student discipline in soap making required that all students wear protective clothing and work in a well-ventilated laboratory. Therefore, these items could not be used to evaluate learning success.

The students' skill scores in making solid soap from vegetable oil using the conventional "No Heat" method are shown in Table 4.

Determining the appropriate amount of alkali for saponification, based on the saponification number of each vegetable oil, is crucial for advancing scientific knowledge and practical applications of chemical thermodynamics (Paphane et al., 2022). However, manual methods for calculating the water-alkali solution required for saponification are not feasible because the saponification numbers of most commercial lipid substrates are still unavailable in the literature. To address this issue, an interactive software tool called a soap calculator is used to design stoichiometrically balanced soap formulas. This software accurately and instantly calculates the amount of water-alkali solution required for saponification, in a completely stoichiometric manner. The most important feature of this calculator is that it provides the average saponification value of various oils and fatty acid chains available in the commercial market. Additionally, it also predicts soap hardness, cleaning power, softening ability, foaming ability, and iodine value. Students must input several software requirements, such as the type of alkali agent used, the water-alkali ratio,

Table 4. Score of students' skills in making used cooking oil soap using the cold method

Indicator	Sub Indicators	Average Soap- Making Skill Score*)	
		Practice 1	Practice 2
accuracy of preparation of the water phase (alkali solution)	Students can use the Soap Calculator application to calculate the amount of NaOH alkali and distilled water needed in the soap formula	1.37	2
accuracy of selection and preparation of the oil phase	Students can use the Soap Calculator application to select the vegetable oils and to determine the properties of soap (hardness, cleansing, conditioning, bubbly, and creamy)	0.45	2
The accuracy of mixing the water phase into the oil phase	The accuracy of mixing the water phase into the oil phase. Students mix the alkali solution and the oil mixture when the temperatures of both phases are the same, at 40 °- 45 °C.	1	2
	Students stir the soap mixture until it traces (when a spoon is touched to the mixture, the mark will remain for a few seconds).	1.47	2.26
	Students add fragrance and coloring and stir until it is completely mixed.	1	2
	Students pour the soap into the mold when the trace point has been reached.	2	2.26

*) The average soap-making skill score was calculated for 38 students in the PjBL group

the choice of oil, the mass of oil, the percentage of superfats, and the percentage of additives. Therefore, students' ability to use the soap calculator application is used as an indicator of the success of PjBL learning.

Figure 4 shows an example of calculation using the soap calculator application *SoapCalc.* Based on a soap formula with an oil phase consisting of 225 g of used cooking oil (usually derived from palm oil), 60 g of coconut oil, and 15 g of olive oil, the recipe requires 42.68 g of NaOH and 144 g of water.

The first soap-making assessment showed that most students difficultly to use the *SoapCalc*

Total oil weight	300 g
Water as percent of oil weight	38.00%
Super Fat/Discount	5%
Lye Concentration	27.242%
Water : Lye Ratio	2.6708:1

Sat : Unsat Ratio	56 : 44
Iodine	46
INS	166
Fragrance Ratio	30
Fragrance Weight	9 g

	Pounds	Ounces	Grams
Water	0.251	4.02	114.00
Lye - NaOH	0.094	1.51	42.68
Oils	0.661	10.58	300.00
Fragrance	0.020	0.32	9.00
Soap weight before CP cure or HP cook	1.027	16.43	465.68

#		Oil/Fat	%	Pounds	Ounces	Grams
1		Olive Oil pomace	5.00	0.033	0.53	15.00
2		Palm Oil	75.00	0.496	7.94	225.00
3		Coconut Oil, 76 deg	20.00	0.132	2.12	60.00
		Totals	100.00	0.661	10.58	300.00

Soap Bar Quality	Range	Your Recipe
Hardness	29 - 54	54
Cleansing	12 - 22	14
Conditioning	44 - 69	43
Bubbly	14 - 46	14
Creamy	16 - 48	40
Iodine	41 - 70	46
INS	136 - 165	166

Lauric	10
Myristic	5
Palmitic	36
Stearic	5
Ricinoleic	0
Oleic	34
Linoleic	9
Linolenic	0

Figure 4. Screenshot of soap formula calculation results with the *soapcalc* application

to determine the properties of the resulting soap based on the type and amount of vegetable oil used in the formula (score 0.45), while selecting the type of alkali and calculating the amount of alkali and distilled water needed in the soap formula was easier to understand (score 1.37). Students are likely to be unfamiliar with the terms used to evaluate soap quality, including Hardness, Cleansing, Conditioning, Bubbly, Creamy, Iodine, and INS, which are relatively new. Consequently, a thorough explanation of these terms was provided before the second batch of soap-making. The students learned that the varying fatty acid content of each type of oil significantly determines the quality of the soap. Vegetable oils containing saturated fatty acids (lauric, myristic, palmitic, and stearic acids) produce a hard texture and lather. In contrast, vegetable oils containing unsaturated fatty acids (oleic, linoleic, and linolenic acids) provide a conditioning effect.

The soap calculator assessment results (Figure 4) show that the soap produced falls within the ideal range (Hardness: 54, Cleansing: 14, Conditioning: 43, Bubbling: 14, Creamy: 40, Iodine: 46, and INS: 166). Only the Conditioning value is slightly below the standard, at 43, within the ideal range of 44-69. Using the soap calculator application to formulate a soap recipe and interpret its qualities directly increases students' knowledge of soap benefits and uses. Consequently, when tasked to create different types of soap, students performed well - even when asked to expand upon existing formulas in the soapmaking process.

Procedural inefficiencies occurred during the molding phase: delays in pouring the soap solution into the mold and continued stirring even after the trace point was reached, resulting in a very thick soap mass that was difficult to pour. The resulting soap had a rough surface to the touch. Conversely, another observed error was that some soaps exhibited high plasticity and could not be removed from the mold after 24 hours. This may be due to stopping the stirring process before the trace was reached, or to the essential oil fragrance concentration exceeding the usual 3% of the oil-phase soap weight (9 grams). This resulted in the mass becoming more liquid, requiring 72 hours of drying before it could be removed from the mold.

A nonparametric test (Wilcoxon test) was used to assess the significance of changes in students' practical soap-making skills after two practical classes. The results showed a highly significant increase ($p < 0.001$) in their practical soap-making skills.

The Exhibition of Soap From used Cooking Oil

In the final stage of the PjBL learning process for making used cooking oil soap, students worked in groups to make soap, which was then exhibited and sold to the public. This exhibition was held in collaboration with students from Muhammadiyah Lajoa Middle School. It was attended by officials from the Education and Culture Office, the Muhammadiyah Branch Chairperson, and other relevant stakeholders.

This activity provides an opportunity for students to gain experience and confidence in soap making as beginners in entrepreneurship for their future. Although all products sold out during the event, this study focused solely on the soap-making process. It did not investigate the potential use of this project to teach financial literacy metrics. A limitation of this study is that it did not investigate the potential of this project to teach financial literacy and entrepreneurship metrics. This area warrants further development in future research.

Project-Based Learning (PjBL) is a modern teaching method believed to improve students' environmental and scientific literacy. The application of PjBL in the integrated learning of natural and socio-humanistic sciences and techniques is efficient and effective, involving students in active work with minimal financial resources within a given time frame. This project has the potential to foster eco-responsible behavior and "ecological civic behavior" in an educational setting within the framework of Citizenship Education curricula. By implementing an organic waste recycling project, students are expected to increase their environmental commitment and awareness of the recycling/ consumption processes (Emilie, 2015).

Through this experience, they will acquire skills to analyze different types of waste and technical competencies to transform residual waste into value products. Unlike conventional waste management, this approach can generate eco-friendly agricultural alternatives that reduce reliance on synthetic chemicals. The social studies perspective assesses the social outcomes of this experience, students' understanding of the circular economy's basic principles, and how these changes affect their social interactions. Converting wasted vegetable oil into soap is applicable in every home and could generate some income (Azme et al., 2023; Al-Balushi and al-Aamri, 2014; Lotero et al., 2005; Kim, Kim & Chung, 2015; Tsai, 2019; Zamakhsyari et al., 2024).

This study is a continuation of prior research on implementing the science curriculum using the PjBL approach. This study demonstrates that liquid organic fertilizer from bamboo shoots can be an interesting topic for PjBL classroom activities. Using a practical, project-based approach to implement PjBL classroom activities can foster students' creativity and independence. They are given the freedom to gather information and complete a variety of tasks to demonstrate their communicative, creative, and technical skills. In addition, environmental community service activities can inculcate positive environmental attitudes and behaviors in students, helping them manage waste and reduce pollution by producing sustainable products. In addition to making hands-on fabrication of a direct product, students worked to become more confident speakers by preparing for and delivering peer presentations.

CONCLUSION

The implementation of the Project-Based Learning (PjBL) model, which focuses on making soap from used cooking oil, has proven effective as a superior science learning method compared to traditional methods at the junior high school level. The study found that students participating in the PjBL program demonstrated a significantly greater understanding of environmental and science concepts than the control group. The PjBL method had a positive and significant impact on students' environmental literacy, scientific literacy, and soap-making skills at Muhammadiyah Lajoa Junior High School. Integrating real-world environmental issues (such as used cooking oil) into the science curriculum makes learning more meaningful, and PjBL can be a key approach for teachers to equip students with practical skills for everyday life. It is a strategy that simultaneously increases student engagement, independence, and environmental awareness in the classroom.

DECLARATION OF GENERATIVE AI USAGE IN THE WRITING PROCESS

During the writing of this manuscript, the author used Turnitin to assess the percentage of plagiarism and the use of AI. The author has reviewed the content generated by this tool and assumes full responsibility for the published article.

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