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Liquid Organic Fertilizer Products From Eggshell Waste For Grade X High School Students

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ABSTRACT

Environmental pollution caused by household organic waste requires contextual and solution oriented learning. This study aims to analyze the quality of liquid organic fertilizer (LOF) made from eggshell waste through the application of E-STREAM Project-Based Learning (PjBL) on environmental pollution. The study employed a quasi experimental method using a Posttest Only Non Equivalent Control Group Design involving 60 tenth grade students at SMAN 1 Sukakarya, consisting of 30 students in the experimental class and 30 students in the control class. Data were collected using observation sheets and a product assessment rubric, and were analyzed using quantitative descriptive analysis to evaluate the implementation of learning and the quality of students' LOF products. The results showed that the implementation of learning was categorized as very good, with teacher activity reaching 98.03% and student activity reaching 86.76%. The average quality of LOF products in the experimental class was 93.50% (very good), which was higher than that of the control class at 82.33% (good). These findings indicate that E-STREAM based PjBL can improve the quality of students' products and provides an alternative contextual PjBL approach for biology and environmental education.

1. Introduction

Environmental pollution caused by increasing waste volume remains a serious problem in many large cities in Indonesia, including Bandung. The Bandung City Environmental Agency reports that the city produces approximately 1,500 tons of waste daily, while the current waste management capacity available to the community is still insufficient to handle all the waste generated (Bandung City Environmental Agency, 2024). As a result, hundreds of tons of waste still need to be transported to landfills or piled up in various temporary storage areas. This situation demonstrates that waste management at source remains a significant challenge, requiring active public participation to reduce and utilize waste generated (Saufi et al., 2024).

Most waste originates from household activities. According to data from the Bandung City Environmental Agency in 2024, approximately 60% of daily waste generated comes from household waste (Bandung City Environmental Agency, 2024). If not managed properly, this waste can cause environmental pollution, reduce sanitation quality, produce unpleasant odors, and increase the burden of urban waste management. Household waste is a major contributor to urban problems, with organic waste being the largest contributor (Oppusunggu et al., 2025).

This situation demonstrates the need for contextual learning that connects biology material to real life issues relevant to students' daily lives. One of the most relevant topics for this purpose is environmental pollution. Environmental pollution remains a global issue requiring serious attention due to increasing human activity and the resulting increase in waste. This organic waste originates from food scraps and other daily household activities. Studies show that organic waste remains a major contributor to waste in Bandung City, while its management still relies on a landfill system, which can cause soil, air, and soil pollution if not handled properly. One type of household waste that is commonly found but has not been utilized efficiently is eggshell waste (Oppusunggu et al., 2025)

One type of household organic waste that is often overlooked is eggshell waste. Eggshells are often considered waste, even though they actually contain calcium carbonate ($CaCO_3$) and various minerals that can support plant growth. This makes eggshells potentially useful as a raw material for liquid organic fertilizer (LOF) (Sugiharto et al., 2024). Using eggshell waste to make liquid organic fertilizer is a waste management method that can help reduce environmental pollution while increasing the economic value of household waste (Hasibuan et al., 2021). In addition to providing ecological benefits, converting waste into useful products can also be a meaningful and relevant learning experience. Through this activity, students have the opportunity to directly understand the concept of environmental pollution by identifying problems, designing solutions, conducting experiments, and evaluating the products they create (Lestari & Saputra, 2023)

Research by (Afiyah et al., 2021), has shown that liquid organic fertilizer (LOF) produced from eggshell waste contains essential nutrients that promote plant growth while providing an environmentally friendly alternative to chemical fertilizers. In addition, the management of household organic waste is an important strategy for reducing waste and has been actively promoted by the Bandung City Government through various community-based waste management programs (Hasibuan et al., 2021). Encouraging community participation in managing organic waste at the household level is considered a key approach to supporting sustainable development and creating a cleaner and healthier environment. These findings are consistent with previous studies reporting that integrating Project-Based Learning (PjBL) with the STREAM approach provides authentic learning experiences by connecting scientific concepts with real world environmental issues. The present findings further demonstrate that the E-STREAM approach can be effectively implemented to support product oriented biology learning through contextual environmental projects, enabling students to apply scientific knowledge while producing meaningful and environmentally beneficial products (Utami et al., 2025)

The problem of environmental pollution in Bandung City can be used as a learning context close to students' lives to connect Biology concepts with real life problems. In environmental pollution learning, students are not only required to understand the concepts theoretically, but also to be able to identify problems and design applicable solutions (Saufi et al., 2024). Although various waste reduction programs have been implemented, public awareness of managing waste at its source remains relatively low (Pasaribu & Simatupang, 2020). Therefore, contextual, problem solving oriented learning is needed through activities that process waste into useful products (Saufi et al., 2024). These activities can provide meaningful learning experiences because they actively involve students in identifying problems, designing solutions, implementing projects, and producing results, thereby increasing environmental awareness and developing 21st century skills (Rohman, 2024).

One learning model that can help achieve this goal is PjBL. This model provides students with the opportunity to identify problems, design solutions, implement projects, and create tangible, useful products. This study involved a project to create liquid organic fertilizer from eggshell waste, a simple effort to reduce environmental waste and increase the use of household waste (Nurjanah & Purwantoyo, 2023). To make learning more comprehensive and meaningful, the PjBL model is combined with the E-STREAM approach, which includes Environment, Science, Technology, Religion, Engineering, Art, and Mathematics. This approach allows students to see environmental problems from various perspectives (Nadya et al., 2024). Environmental efforts are carried out by reducing eggshell waste, Science is involved through understanding the fermentation process and the quality of fertilizer fermentation, Technology is used through the application of information technology and supporting tools, Religion contributes by instilling the values of human responsibility in protecting the environment, Engineering is applied through product design, Art is included through creative product presentations, and Mathematics is used through calculating material composition and analyzing the results (Utami et al., 2025).

According to (Agustina et al., 2022), the STREAM approach can be one of the best options for PjBL, which is carried out through the creation of liquid organic fertilizer using eggshell waste as a material on the topic of environmental pollution. This project was chosen because it successfully combined all aspects of E-STREAM, from identifying environmental problems, applying scientific concepts, using simple technology, through the product design process, incorporating religious values for environmental protection, demonstrating creativity in product presentation, and using mathematical concepts to calculate materials and the manufacturing process (Azizah et al., 2019).

The uniqueness of this study lies in the integration of PjBL with the E-STREAM approach through a project involving the production of liquid organic fertilizer (LOF) from eggshell waste as a contextual solution to environmental pollution. Unlike previous studies that primarily examined the effects of STREAM based learning on students' cognitive abilities or higher order thinking skills, this study specifically focuses on evaluating the quality of products generated through E-STREAM based PjBL. The findings are expected to contribute to the development of contextual and environmentally oriented biology learning while providing an alternative PjBL strategy for senior high school students. Therefore, the objective of this study was to analyze the quality of liquid organic fertilizer (LOF) produced from eggshell waste through the implementation of E-STREAM PjBL on the topic of environmental pollution.

2. Methodology

This research was conducted from May 12 to May 26, 2026, at SMAN 1 Sukakarya. The study population included all tenth grade students in the 2025/2026 academic year taking Biology, specifically the topic of environmental pollution. This study involved 60 students, with 30 students in the experimental class and 30 students in the control class. The sample was selected using *purposive sampling*. Students were selected based on their academic ability, student characteristics, and recommendations from the Biology teacher (Abubakar, 2021).

This study employed a quasi experimental method using a Posttest Only Non Equivalent Control Group Design, as presented in Table 1. The experimental class was taught using PjBL integrated with the E-STREAM approach (Environment, Science, Technology, Religion, Engineering, Art, and Mathematics), while the control class received conventional PjBL without E-STREAM integration. At the end of the learning process, students in both classes were assessed based on the quality of the liquid organic fertilizer (LOF) products they produced.

Table 1. Posttest Only Non Equivalent Control Group Design

Class	**Treatment**	**Posttest**
Experiment	X	O_1
Control	-	O_2

Instructions:

X = E-STREAM PjBL
O_1 = Product quality assessment for the experimental class
O_2 = Product quality assessment for the control class

The learning activities were conducted over three meetings, with each meeting lasting 2 x 45 minutes. In the experimental class, the learning process followed the syntax of E-STREAM based Project-Based Learning. During the first meeting, the teacher introduced an environmental pollution issue related to household organic waste and guided students to identify the problem (Reflection). Students then collected information from textbooks, scientific articles, and other learning resources regarding the characteristics of eggshell waste, the fermentation process, and the production of liquid organic fertilizer (Research). Based on the collected information, students designed the project, determined the required materials and equipment, and prepared the procedures for producing liquid organic fertilizer.

During the second meeting, students conducted preliminary activities by preparing the materials and equipment and performing the fermentation process to produce liquid organic fertilizer (Discovery). They then implemented the project by producing liquid organic fertilizer from eggshell waste according to the established procedures (Application). Throughout this stage, the teacher acted as a facilitator by supervising the project, providing guidance and feedback, and ensuring that students integrated the principles of Environment, Science, Technology, Religion, Engineering, Art, and Mathematics into the project activities.

During the third meeting, students evaluated the fermentation results through organoleptic observations, assessed the quality of the fertilizer, and tested its effectiveness on the growth of water spinach plants. Students then prepared project reports and presented their products to the class (Communication). The teacher facilitated classroom discussions and reflection to help students evaluate the strengths and limitations of their products and relate the project outcomes to environmental pollution issues. In the control class, learning was also conducted over three meetings using conventional PjBL. Students identified environmental pollution problems, designed and produced liquid organic fertilizer, and presented their project results. However, the learning process did not explicitly integrate the Environment, Science, Technology, Religion, Engineering, Art, and Mathematics components into the project activities.

Research data were collected using observation sheets to evaluate the implementation of learning and a product assessment rubric to assess the quality of students' liquid organic fertilizer products. Prior to implementation, both instruments were validated through expert judgment by two Biology Education lecturers and one Biology teacher to ensure their content validity. The validation process focused on the relevance of the indicators, the clarity of the assessment criteria, the appropriateness of the language, and the suitability of the instruments with the research objectives and learning outcomes. The instruments were revised based on the validators' suggestions before being used in the study.

The observation sheets were developed based on the learning stages implemented in both classes. Teacher activities were assessed using a Guttman scale with "Yes" and "No" responses, whereas student activities were evaluated using a four point Likert scale. Classroom observations were conducted by observers during each meeting to assess the implementation of learning activities. The quality of the liquid organic fertilizer products was assessed based on three aspects: organoleptic characteristics, fermentation quality, and effectiveness in promoting the growth of water spinach plants. The collected data were analyzed using quantitative descriptive analysis to describe the implementation of learning and the quality of students' liquid organic fertilizer products. The indicators used to observe the implementation of learning activities are presented in Table 2.

Table 2. Observation Sheet Grid for Learning Implementation

Observation Indicators
• Reflection Stage (Thinking) • Research Stage (Design) • Discovery Stage (Create) • Application Stage (Create, Test) • Communication Stage (Present)

Data were then analyzed using quantitative descriptive analysis to determine the implementation of learning and the quality of students' LOF products. The assessment rubric used to evaluate the quality of the liquid organic fertilizer products is presented in Table 3.

Table 3. Assessment Rubric for the Evaluation and Effectiveness of Liquid Organic Fertilizer on Water Spinach Plants

Aspect	Indicator	Criteria	Category	Score
Organoleptic	Liquid Organic Fertilizer Color	Color is not appropriate	Poor	1
		Light brown	Fair	2
		Bright yellowish brown	Good	3
		Dark brown	Very good	4
	Liquid Organic Fertilizer Aroma	The stench of organic waste	Poor	1
		Weak sour aroma, the smell of raw materials is still dominant	Fair	2
		The sour fermented aroma is not fresh	Good	3
		The distinctive aroma of fresh sweet and sour fermentation like tape	Very good	4
	Clarity	The solution is not homogeneous and there is sediment	Poor	1
		The solution is starting to become homogeneous but there is still sediment	Fair	2
		The solution is homogeneous in part of the container	Good	3
		The solution is homogeneous throughout the container	Very good	4
Fermentation Quality	Product pH	pH < 4 or > 8	Poor	1
		pH 4-5 or 7-8	Fair	2
		pH 5-6 or 6-7	Good	3
		pH ideal 5-7	Very good	4
	Fermentation Success	No bubbles, mold contamination, or foul odor	Poor	1

		Bubbles are starting to become active, no mold	Fair	2
		Active fermentation bubbles are starting to form	Good	3
		Active bubbles, no mold contamination, and typical fermentation aroma	Very good	4
Plant Test	Plant Height	≤ 5 cm	Poor	1
		> 5-8 cm	Fair	2
		> 8-11 cm	Good	3
		> 11 cm	Very good	4
	Number of Leaves	≤ 2 strands	Poor	1
		3-4 strands	Fair	2
		5-6 strands	Good	3
		≥ 7 strands	Very good	4

Source: Developed by the authors based on (Agustina et al., 2017).

3. Results and Discussion

Implementation of PjBL Learning Based on the E-STREAM Approach

Students in the experimental class participated in learning activities across three sessions, using the PjBL model combined with the E-STREAM approach. During the reflection stage, the teacher helped the students recognize environmental issues caused by household waste, particularly eggshells. Next, during the research phase, the students looked for information on the features of organic waste, how fermentation works, and how eggshells can be used as a material to make liquid organic fertilizer. During the discovery phase, students created a project plan, selected the necessary tools and materials, and talked about the steps to make liquid organic fertilizer. During the application phase, students made liquid organic fertilizer and tested the quality of the product.In the communication phase, they shared their project results, got feedback, and thought about the benefits of the product they created. Each learning stage included parts of Environment, Science, Technology, Religion, Engineering, Art, and Mathematics, helping students learn in a way that connects to real-world environmental issues (Agustina et al., 2022).

At the same time, the control group used the traditional PjBL approach, which is usually taught by biology teachers in schools. Learning happened in steps like giving some kind of input, finding out what's wrong, gathering information, working with that information, checking if it's correct, and finally coming up with an answer. In the control class, students kept learning about environmental pollution, but they didn't take part in any project-based activities that used the E-STREAM method. The differences in the learning stages used in the experimental class and the control class are shown in Figure 1.

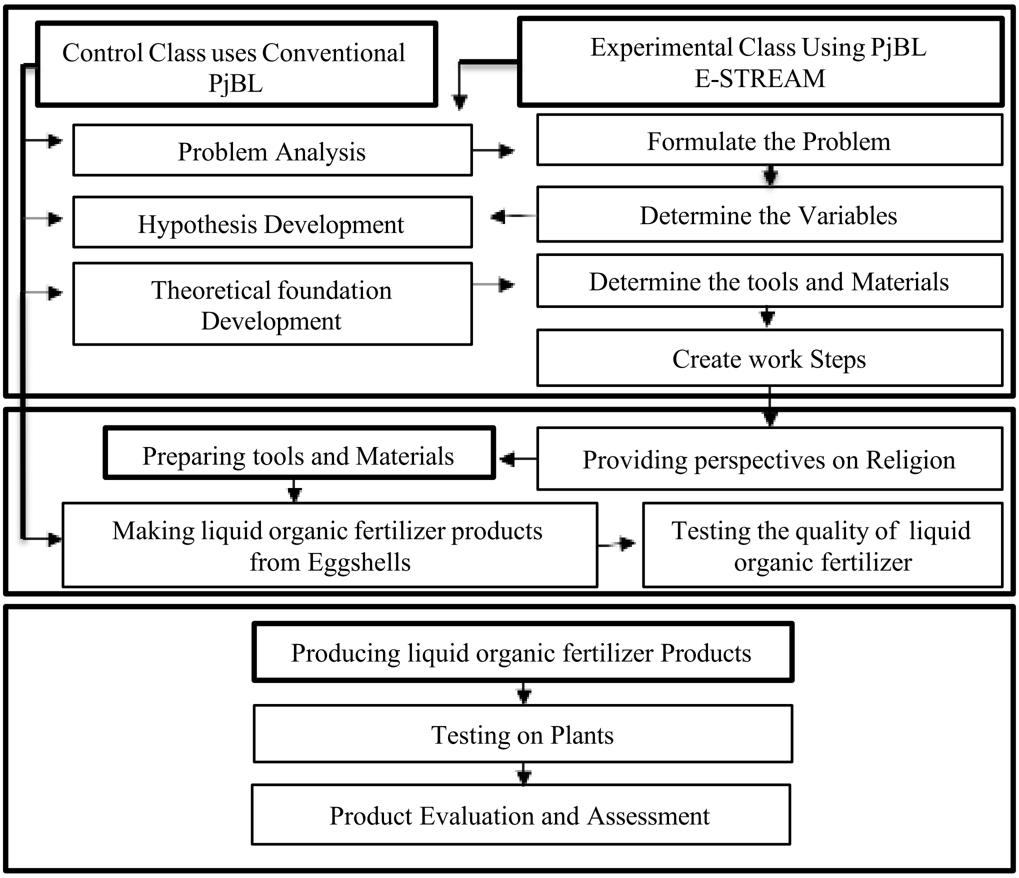

Figure 1. Stages of Learning Implementation in Experimental Classes and Control Classes

The learning implementation observation sheet was used only in the experimental class to check how well the E-STREAM approach was being carried out as part of the research treatment. No observations were made during the control class because the teaching followed traditional methods and did not use E-STREAM syntax. The results from these observations are shown in Table 4.

Table 4. Results of the E-STREAM PjBL Learning Implementation in the Experimental Class

Teacher		Student	
Value	**Criterion**	**Value**	**Criterion**
98,03	Very good	86,76	Very good

From the results in Table 4, it's clear that the E-STREAM-based learning method was carried out successfully. The share of teachers participating was 98.03%, and the share of students participating was 86.76%. These results show that every step of the learning process was carried out properly based on the E-STREAM framework, which helped students stay involved and led to the creation of good quality liquid organic fertilizer. The strong level of teacher involvement shows that every part of the E-STREAM method was followed exactly as planned (Nadya et al., 2024). Similarly, the high level of student involvement means that students were really active throughout the whole learning process, from finding problems and collecting useful information to creating and carrying out the project, as well as sharing the final result. By getting involved actively, students were able to use what they learned about biology in a real-world way, and they made liquid organic fertilizer that met the required standards for product quality (Pangestu et al., 2024).

Product Assessment of Egg Shell Waste Liquid Organic Fertilizer

The study shows that students evaluated the liquid organic fertilizer they made to check how good its quality was after taking part in the learning activities. The product was assessed using three key factors: things like how it looks, smells, and tastes, the quality of the fermentation process, and results from plant tests. A product is seen as great when it fulfills every standard that is used to judge it. In both the experimental and regular classes, assessments of product performance were carried out (Nirmayani & Dewi, 2021). The product evaluation criteria are listed in Table 3.

The evaluation results show that every group in both the experimental and control classes made products that were rated as excellent. The analysis of the product indicators showed that the experimental group performed better than the control group in all areas of product evaluation. The outcomes from evaluating the Liquid Organic Fertilizer (LOF) product in both the experimental and control groups are shown in Table 5.

Table 5. Liquid Organic Fertilizer from Egg Shell Waste Product Assessment Results Based on Indicators

Product Indicator	Experiment (%)	Category	Control (%)	Category
1. Organoleptic (color, aroma, texture)	95,00	Very Good	84,50	Good
2. fermentation quality	93,50	Very Good	80,00	Good
3. Plant Test	92,00	Very Good	82,50	Good
Average	**93,50**	**Very Good**	**82,33**	**Good**

Looking at Table 5, which shows the results of assessing the Liquid Organic Fertilizer made from egg shell waste, we can see that students in the experimental class had an average score of 93.50%, which is considered excellent. On the other hand, the control class had an average score of 82.33%, which is considered good. This shows that students in the experimental class made better liquid organic fertilizer by following a more organized way of planning, making, and checking their product. The E-STREAM method lets students use science and engineering ideas to figure out what materials are used, manage the fermentation process, and make a good quality product (Azizah et al., 2019).

The higher quality of liquid organic fertilizer products in the experimental class indicates that integrating the E-STREAM approach into PjBL provided students with meaningful learning experiences through authentic environmental projects. Students were actively involved in identifying environmental problems, designing project plans, producing liquid organic fertilizer, evaluating the product, and communicating the project outcomes (Kusuma Ningtyas et al., 2024). These learning experiences enabled students to apply biological concepts directly to solve environmental problems, resulting in products that better fulfilled the established assessment criteria (Satria et al., 2025).

This finding is also supported by (Sundari et al., 2025) who stated that PjBL encourages students to become actively involved throughout the learning process, enabling them to construct knowledge through authentic experiences. In the present study, students' active participation during the Reflection, Research, Discovery, Application, and Communication stages enabled them to apply biological concepts directly to the production of liquid organic fertilizer, thereby improving product quality (Sundari et al., 2025).

Organoleptic Test

For the organoleptic indicator, the experimental class scored 95.00%, which was higher than the control class, which scored 84.50%. These results indicate that the product from the experimental class had better physical characteristics in terms of color, odor, and texture. The uniform dark brown color, distinctive fermentation aroma, and homogeneous texture indicate that the fermentation process was proceeding optimally. This situation is likely because students in the experimental class had a better understanding of the factors influencing fermentation success, enabling them to produce a more uniform and stable product (Afiyah et al., 2021).

The high organoleptic score in the experimental class is thought to be due to the students' ability to control the fermentation process by more precisely adjusting the composition of ingredients and fermentation time. This is in line with research conducted by (Itamah et al., 2025), which reported that liquid organic fertilizer made from organic waste and eggshells produced good physical characteristics and nutritional content when the fermentation process was carried out optimally. This study shows that eggshells can be a good source of minerals, especially calcium, which helps improve the quality of liquid organic fertilizer. Furthermore, the use of EM4 bioactivator also plays a crucial role in accelerating the decomposition of organic matter. The microorganisms in EM4 help break down complex compounds into simpler forms, thus facilitating and accelerating the production of high-quality, mature liquid organic fertilizer (Meo, 2022).

Fermentation Quality

The nutrient content indicator showed the largest difference between the two classes. The experimental class scored 93.50%, while the control class scored 80.00%. The 13.50% difference indicates that the experimental class achieved a higher nutrient content than the control class better able to produce fertilizer with a higher nutrient content. The difference in nutrient content was optimal. The high 13.50% in the control group was related to students' interest in determining the ratio of ingredients during the fertilizer production process. This indicates that the use of EM4 as a bioactivator can accelerate the decomposition of organic matter and improve the quality of the resulting liquid organic fertilizer. Microorganism activity during fermentation plays a crucial role in converting organic matter into nutrients that are more readily available to plants (Widyabudiningsih et al., 2025).

In the E-STREAM approach, students are taught to use mathematical concepts to calculate composition and technical concepts to plan an effective fermentation process. This results in a more complete decomposition process and produces more nutrients available to plants. This is in line with research by (Putri et al., 2025), which states that eggshell waste has a high calcium content and can improve the quality of liquid organic fertilizer if fermented properly. Using eggshells as waste can increase the mineral content of fertilizers and also provides an environmentally friendly solution through waste management. Eggshells are a source of organic calcium rich in high mineral content, thus having high functional value. Therefore, eggshells have the potential to be used as a raw material for various agricultural and environmental products (Sugiharto et al., 2024)

Plant Test

In the plant testing indicator, the experimental class scored 92.00%, while the control class scored 82.50%. The difference shows that the liquid organic fertilizer (POC) produced through E-STREAM-based learning is more effective in supporting the vegetative growth of water spinach plants (Addeka Nurrahmi et al., 2023). The effectiveness of fertilizer is evaluated based on two indicators: plant height and the number of leaves. Higher scores in the experimental group show that plants given POC from the E-STREAM project-based initiative grew better than plants in the control group. This condition shows that the fermentation process produces fertilizer with good quality that can supply nutrients more effectively, helping plants grow better (Putri et al., 2025).

In the high plant indicator, better results in the experimental group show that the POC produced is able to provide nutrients that support cell division and cell elongation during the vegetative growth phase. The calcium and other minerals in eggshell waste become more available after fermentation, allowing plants to absorb them more effectively. The availability of these nutrients helps plants grow better and supports the development of stronger stems. These results agree with the research by (Addeka Nurrahmi et al., 2023), who reported that liquid organic fertilizer made from eggshell waste can improve plant growth by providing easily absorbed nutrients (Putri et al., 2025). The number of leaves indicator also shows better results in the experimental class compared to the control class. The number of leaves is one of the factors that shows how well the plant is growing vegetatively because it is related to the plant's ability to perform photosynthesis. The more leaves a plant produces, the more biomass it can generate. Therefore, the higher number of leaves in the experimental group shows that the liquid organic fertilizer produced has better quality in supporting the formation and development of leaves, leading to more optimal plant growth (Putri et al., 2021).

The difference in the test results of the plants between the two classes is not only affected by the quality of the liquid organic fertilizer produced, but also by the learning process used during the project activity. Students actively participate by identifying environmental issues, preparing the compost mixture, controlling the fermentation process, and evaluating the effectiveness of the fertilizer by observing plant height and leaf count through the steps of Reflection, Research, Discovery, Application, and Communication. This involvement helps students understand the factors that affect the quality of liquid organic fertilizer, and also results in a more effective product that supports plant growth better. This finding supports the results from the research by (Putri et al., 2025) and (Sundari et al., 2025), who found that using Project-Based Learning combined with an interdisciplinary approach can provide a real and meaningful learning experience, and also improve the quality of products created by students. Examples of the liquid organic fertilizer products and the water spinach growth test are shown in Figure 2.

Figure 2. Eggshell based liquid organic fertilizer (a) and results of water spinach plants treated with liquid organic fertilizer (b)

According to field records, students were able to use various scientific information sources during the process of making liquid organic fertilizer and plant testing. This ability helps students create work procedures, assess the fermentation process, and prepare experiment reports in a structured way. Figure 2a shows the liquid organic fertilizer made from eggshell waste produced by the students, while Figure 2b shows the result of applying it to water spinach plants. These results support the data in Table 5, which shows that the experimental product class has better quality than the control class based on organoleptic aspects, fermentation quality, and plant testing. The quality of the product improves because each component of E-STREAM is integrated throughout the learning process. Unsur Science helps students understand the principles of fermentation and the characteristics of good liquid organic fertilizer. Technology supports the use of information sources and equipment. Engineering helps in designing the work procedures and solving problems during fermentation. Mathematics is used to determine the composition of materials and the duration of fermentation. Art develops creativity in presenting the product, while Religion fosters care for the environment by turning waste into useful products. Combining all these components makes the learning process more contextual and also helps improve the quality of the liquid organic fertilizer produced (Utami et al., 2025). The overall implementation of the E-STREAM approach in the Project Based Learning process is illustrated in Figure 3.

Environmental Pollution Analysis (Learning Outcomes & Learning Objectives)
Learning objectives: Students can create solutions to environmental problems and relate them to the function of organic waste found in the environment.
(Production of Liquid Organic Fertilizer)

Science Content & Scientific Process Liquid Organic Fertilizer

1. Identification of the types and composition of organic waste raw materials (types of eggshells)
2. Liquid Organic Fertilizer manufacturing techniques
3. Three factors for process success (material concentration, environmental conditions, fermentation time)
4. Characteristics of successful Liquid Organic Fertilizer products

Eggshell Waste Liquid Organic Fertilizer Manufacturing

Experimental Class
(PjBL based on E-STREAM Student Worksheet)

1. Problem identification (Reflection) Thinking
2. Gathering information on raw materials and additional materials for making Liquid Organic Fertilizer (Research) Design
3. Initial experiment (Discovery) Create
4. Liquid Organic Fertilizerproduction (Application) Test
5. Presentation of results (Communication) Presentation

Advantages:
1. Supports contextual project based learning
2. Facilitates the production of quality products

Disadvantages:
Requires adequate preparation by teachers and students to implement interdisciplinary project-based learning effectively.

Control Class
(Conventional PjBL)

1. Observing
2. Asking
3. Trying
4. Reasoning
5. Communicating

Advantages:
1. Structured and easy to implement learning steps
2. Time efficient and suitable for reinforcing basic concepts

Disadvantages:
Interdisciplinary integration is not optimal, focus is on the scientific process, and there is minimal real world context and application of environmental values.

LKPD PjBL with E-STREAM approach

E	S	T	R	E	A	M
Analysis of the impact of waste on the environment and its role in implementing the 3R concept.	• Organic waste • Fermentation	***High-tech:*** 1. Digital scale 2. Blender ***Low-tech:*** 1. Stirrer 2. Bottle 3. Measuring cup 4. Funnel	Pancasila student profile 1: believe in, fear God Almighty	1. P 2. D 3. B 4. U	Making liquid organic fertilizer product packaging that is economical and environmentally friendly	1. Ingredient composition 2. Count the number of tools

Product Assessment

Figure 3. Implementation of the Environmental-STREAM Approach in learning how to make liquid organic fertilizer (LOF) from eggshell waste

Research findings show that using E-STREAM in Project-Based Learning doesn't just increase student engagement, but also produces liquid organic fertilizer with better organoleptic qualities, fermentation quality, and plant testing effectiveness. By going through the steps of Reflection, Research, Discovery, Application, and Communication, students are able to connect biology concepts with solving environmental problems by making liquid organic fertilizer from eggshell waste. This study's findings agree with previous research that shows integrating STREAM with project-based learning can provide a real and meaningful learning experience. Unlike previous studies that mostly focus on students' learning outcomes or creativity, this research specifically evaluates the quality of the product based on three indicators: organoleptic characteristics, fermentation quality, and plant testing. This research shows that integrating the E-STREAM approach into biology learning not only supports contextual learning but also improves the quality of products created by students through environmental problem-solving projects (Rohman et al., 2024).

This study's findings match the results of (Tonda et al., 2024), which show that using Project-Based Learning (PjBL) or Problem-Based Learning (PBL) can help students become more involved in the learning process. Although that is the case, there is a difference in focus between the previous study and this research. However, research by (Tonda et al., 2024), focused more on improving students' learning outcomes, while this research is centered on assessing the quality of the liquid organic fertilizer produced using the E-STREAM approach in Project-Based Learning. Unlike most previous studies that usually measure students' cognitive achievements or creativity, this research uses the quality of the product as the main indicator of learning success. This study's findings support the idea that integrating the E-STREAM approach into biology learning doesn't just help students engage more in the learning process, but also improves their ability to create high-quality products through environmental problem-solving projects. This finding also expands on previous research by showing that product quality can be used as one form of authentic assessment in implementing E-STREAM based on Project-Based Learning, especially in the topic of environmental pollution.

4. Conclusion

This study concludes that applying Project-Based Learning (PjBL) based on E-STREAM successfully improved the quality of liquid organic fertilizer (POC) made from eggshell waste by students compared to traditional PjBL. The improvement is shown through better product quality based on the organoleptic characteristics, fermentation quality, and plant testing indicators. This result shows that integrating aspects of Environment, Science, Technology, Religion, Engineering, Art, and Mathematics into learning can help students create high-quality products and provide an authentic learning experience through project-based activities.

The research findings suggest that the E-STREAM approach could be a promising alternative strategy for teaching biology, especially when covering environmental pollution topics that focus on solving problems in a contextual way through projects. Combining different areas of study in Project-Based Learning helps students connect biology concepts with real environmental issues and create useful products. However, this study is still limited to evaluating the product quality in one school. Therefore, future research is recommended to include a larger and more diverse sample, apply the E-STREAM approach to other biology topics, and examine its impact on critical thinking, creativity, environmental literacy, problem-solving skills, and other learning outcomes.

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