Bioedukasi
Jurnal Biologi dan Pembelajarannya
Vol. 23 No 3, October 2025, page 397-403
e-ISSN: 2580-0094; p-ISSN:1693-3931
DOI: 10.19184/bioedu.v23i3.53737
jurnal.unej.ac.id/index.php/BIOED

The Effectiveness of Discovery Learning-Based Biodiesel Production Practice in Improving Students' Creative Thinking Skills on Renewable Energy Subject Matter

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Article Info
Article history:
Received June 23, 2025
Revised September 13, 2025
Accepted October 24, 2025

Keywords:
Biodiesel production practice
Creative thinking skills
Renewable energy education

ABSTRACT
This study aims to determine the effectiveness of biodiesel production practice in enhancing the creative thinking skills of eighth-grade students at junior high school in Sleman in the renewable energy topic. The research employed a pre-experimental design with a one-group pretest-posttest approach. The sample consisted of 25 students selected purposively from one class. The instrument used was a creative thinking skills test covering indicators of flexibility, fluency, originality, elaboration, and sensitivity to problems. Data were analyzed using descriptive statistics, Shapiro-Wilk normality test, n-Gain calculation, and effect size measurement. The results showed an improvement in students' creative thinking skills with a medium category n-Gain and a very large effect size (1.84), along with a significant difference between pretest and posttest scores ($p < 0.05$). The biodiesel production practice proved effective in developing students' creativity. This study provides important implications for developing practical-based learning methods that are relevant to environmental and renewable energy issues.

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1. INTRODUCTION

Energy is a key driver of economic growth and social progress. Energy consumption and usage levels greatly influence the economic development of a country, primarily fuelled by the use of fossil fuels. However, the prolonged use of fossil fuels has caused numerous environmental problems, especially the rapid depletion of natural resources and increased carbon emissions into the atmosphere. Energy utilization is particularly important in Southeast Asia as it can drive economic development (Maulana et al., 2024)). Growing environmental awareness has encouraged many countries to develop clean technology solutions, ultimately leading to a transition from non-renewable to renewable energy sources (Jaiswal et al., 2022)

Understanding renewable energy is essential in education, especially in the curriculum, because it not only addresses the need for sustainable energy in the future but also increases students' awareness and knowledge of global environmental issues. With the increasing adoption of renewable energy technologies around the world, integrating renewable energy education into formal and informal learning provides students with the opportunity to understand the basic concepts of clean energy while instilling practical values and positive attitudes towards sustainable energy use (Shehzad et al., 2023). The renewable energy sub-material is available in grade eight, in the chapter on work, energy and simple machines

A primary goal of 21st-century education is to develop students' creative thinking skills, enabling them to view problems from new perspectives, generate innovative solutions, and adapt to a constantly changing world. Besides creative thinking, other essential skills for facing 21st-century challenges include communication, collaboration, critical thinking, and problem-solving (Andirasdini & Fuadiyah, 2024). The importance of strengthening students' creative thinking skills has also been emphasized in previous research. Aini & Aini (2023) showed that the engineering design process (EDP) learning model can significantly enhance students' creative thinking and communication skills through hands-on, project-based activities. This finding supports the idea that

contextual and practice-based learning, such as biodiesel production practice, has strong potential to foster students' creativity in science learning. Indonesian students' creative thinking abilities are relatively low, as evidenced by the Global Creativity Index (GCI) in 2015, where Indonesia scored 0.202, ranking 115th out of 139 participating countries ((Fithrunnada & Sunarti, 2023). Furthermore, the 2022 Program for International Student Assessment (PISA) results show that Indonesian students' creative thinking skills lag behind most members of the Organization for Economic Co-operation and Development (OECD), ranking 52nd out of 64 countries, with an average score of 19 compared to the OECD average of (OECD, 2024). Although PISA focuses on assessing literacy in reading, mathematics, and science, these results suggest untapped potential in Indonesian students' creative thinking (Rohmatika et al., 2025). Furthermore, sustainable energy is also a global agenda item the sustainable development goals (SDGs), specifically goal 7 on affordable and clean energy and goal 13 on action on climate change. Education plays a crucial role in supporting the achievement of these goals by instilling awareness, knowledge, and skills in students from an early age (Alisjahbana & Murniningtyas, 2018). One effective approach is practice-based learning or experiential learning, because through direct experience students can connect theory with the realities of everyday life, so that learning becomes more meaningful (Balukh & Chrismastianto, 2025). Integrating STEM learning, which combines science, technology, engineering, and mathematics, can foster student creativity while enhancing other 21st century skills. Thus, developing practice based learning, particularly biodiesel production practices, is not only relevant to the renewable energy curriculum but also supports the development of a creative, innovative, and environmentally conscious generation (Emilidha et al., 2024).

Discovery learning is considered well suited to practice based activities such as biodiesel production. In this approach, students are guided to discover concepts through exploration, observation, and investigation. So they do not simply receive information passively but construct their own understanding from direct experiences (Andika et al., 2025). This is especially important in renewable energy topics, where experiments and hands-on practice allow students to connect theory with real world applications. Previous studies have also shown that discovery learning can enhance creative thinking, since students are encouraged to formulate questions, try out different ideas, and find solution when faced with problems (Windyaningsiwi et al., 2025). Compared to conventional methods such as lectures, discovery learning provides more space for students to engange in problem solving, creativity, and independent analysis (Saputri et al., 2025). In the context of biodiesel production practice, discovery learning fosters flexibility, originality, and elaboration because students are involved in experimenting, observing outcomes, and searching for the best methods. Therefore, applying discovery learning offers a strong pedagogical basis for linking renewable energy practices with the development of creative thinking skills.

Biodiesel production practice was chosen because it provides direct hands-on experience that facilitates students' understanding of renewable energy materials. By engaging in the process of making this alternative fuel themselves, students not only acquire theoretical knowledge but are also actively involved in the process. At every stage, they must observe, analyze, and discover the best methods, which encourages creative thinking. Such practical experiences also motivate students to seek solutions and innovate when facing problems. Therefore, it is believed that biodiesel production practice enhances creativity and raises awareness of the importance of environmentally friendly energy. This is in line with research conducted by Handoyo et al. (2021) which states that learning that is linked to biodiesel practices can improve students' creative thinking skills. Meanwhile, previous research conducted by Kirana et al. (2021) stated that students' creative thinking skills can be trained with learning models that can facilitate students which emphasize more on student activities that carry out the investigation process, especially on renewable energy material. In addition, studies on discovery learning in science experiments confirm its effectiveness in fostering higher-order thinking, creativity, and problem solving because students are encouraged to explore and construct knowledge independently (Oktari & Ardipal, 2024). However, the application of discovery learning in laboratory or renewable energy practices also presents several challenges, such as ensuring safety during experiments, providing sufficient resources and equipment, and preparing teachers with the necessary pedagogical skills (Darling-hammond et al., 2020). These strengths and limitations highlight the importance of careful design and implementation so that discovery learning in renewable energy contexts can maximize its potential to develop creative thinking skills.

The purpose of this study was to determine the effectiveness of biodiesel production practices in improving students' creative thinking skills.

2. RESEARCH METHOD

The type of research in this study comprised all eighth-grade students at junior high school in Sleman for the academic year 2024/2025. The sampling technique used was purposive sampling. The sample consisted of one class, namely class VIII A, with a total of 25 students. This technique was chosen because the class met the criteria required in this study, particularly the coverage of renewable energy topics in the curriculum and the availability of class schedules for treatment. Although purposive sampling allows the selection of participants who best fit the study's objectives, it limits the generalizability of the findings since the sample may not represent the wider student population. This study used a creative thinking skills test consisting of 10 multiple-choice

questions covering the indicators of creative thinking skills: flexibility, fluency, originality, elaboration, and sensitivity to problems. The test items were developed based on established frameworks for creative thinking.

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The data collection process was conducted in two main stages, namely before and after the biodiesel production practice treatment. In the first stage, a pretest was administered to all 25 students from one class, VIII A, aimed at measuring their initial creative thinking skills related to the renewable energy material. In the second stage, after the practice was completed, the same posttest was given to the students to measure the changes and improvements in their creative thinking skills following the treatment. The entire data collection process took place within the school environment during scheduled class hours in coordination with the subject teacher, ensuring that it did not disrupt other learning activities.

The study began by providing students with an explanation of the objectives and benefits of the biodiesel production practice. Next, students took a pretest to measure their initial creative thinking skills before the treatment. Then, the biodiesel production practice was conducted over two weeks, during which students directly participated in the biodiesel- making process under supervision. This activity involved observation, data collection, and independent analysis by the students to develop their creative thinking abilities.

After completing the entire practical activity, students were given a posttest using the same instrument as the pretest to assess the development of their creative thinking skills. The pretest and posttest data were then collected and analyzed using SPSS statistical tests to evaluate the effectiveness of the treatment. The research data were analyzed using descriptive statistical analysis to obtain an overview of students' creative thinking skill scores before and after the treatment. Next, the normality test was conducted using the Shapiro-Wilk method to ensure that the data distribution met the normality assumption. Afterward, the n-Gain value was calculated to determine the extent of improvement in students' creative thinking skills following the biodiesel production practice. Finally, a paired sample t-test was performed to examine the statistical significance of the differences between pretest and posttest scores, and the effect size was calculated to measure the magnitude of the treatment effect.

It is important to note that this study employed a one-group pretest–posttest design without a control group. While this design provides initial insights into the effectiveness of biodiesel production practice, it limits the strength of causal inferences. Future studies are recommended to include a control group and larger samples to strengthen the robustness and generalizability of the findings.

Table 1. N-Gain Criteria

Value Interval	Criteria
N-gain > 1.0	High
0.3 ≤ N-gain < 0.7	Medium
N-gain < 0.3	Low

(Kurniawan & Hidayah, 2020)

The effect size was calculated to measure the magnitude of the treatment's impact on the improvement of student' creative thinking skills.

Table 2 Effect Size Clasification

Effect Size	Interpretation
0 < d < 0.2	Small
0.2 < d ≤ 0,5	Medium
0,5 < d ≤ 0.8	Great
d > 0.8	Very Large

(Widyastuti & Airlanda, 2020)

3. RESULT AND DISCUSSION

The results of this study indicate that the biodiesel production practice is quite effective in improving the creative thinking skills of eighth-grade students of class VIII A at Junior High School in Sleman. A significant difference between pretest and posttest scores, along with a very large effect size, confirms that this activity has a positive impact. Therefore, it can be concluded that learning through direct hands-on practice genuinely helps

students to think more creatively. This finding is in line with the research conducted by Arsitha et al. (2023) which found that when students are directly involved in real activities, their creativity and thinking abilities generally improve. By making biodiesel themselves, students become more active, required to observe, analyze, and find solutions when facing problems. This clearly encourages them to think more flexibly and originally.

Table 3 shows that the results of the descriptive statistical analysis indicate an increase in the average scores of students' creative thinking skills after participating in the biodiesel production practice. Additionally, the range and variation of scores in the posttest are broader compared to the pretest, indicating the development of creative thinking abilities in most students after the treatment.

Table 3. Result of Descriptive Statistical Analysis of Creative Thinking Skills

Descriptive Statistics					
	N	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Pretest	25	1	6	2.84	1.248
Posttest	25	3	9	5.72	1.815

The normality test was conducted using the Shapiro-Wilk test, with the criterion that a significance value (Sig.) greater than 0.05 indicates that the data meet the normality assumption. Based on Table 4, the test results show that the pretest data have a Sig. value of 0.530 and the posttest data have a Sig. value of 0.055, both of which are greater than 0.05. Therefore, it can be concluded that the creative thinking skills data for both measurements are normally distributed and meet the requirements for parametric statistical analysis.

Table 4. Shapiro-Wilk Pretest Posttest Normality Test Analysis Result

C**lass**	**Shapiro-Wilk**		
	Statistic	**df**	**Sig.**
Pretest	.921	25	0.53
Posttest	.921	25	.055

The results of the paired sample t-test showed a significant difference between the pretest and posttest scores of students' creative thinking skills after participating in the biodiesel production practice. The significance value (2-tailed) was 0.000, which is below the 0.05 significance level, indicating that the improvement in students' creative thinking skills after the treatment was statistically significant. Therefore, it can be concluded that the biodiesel production practice is effective in enhancing students' creative thinking skills.

Table 5. Analysis Results of Paired Sample T-Test

C**lass**	**Paired Differences**		**t**	**df**	**Sig. (2-tailed)**
	Mean	**Std. Deviation**			
Pretest Posttest	-2.880	1.394	-10.300	24	.000

Table 6, which presents the N-Gain analysis, shows that the improvement in students' creative thinking skills after participating in the biodiesel production practice falls into the medium category. This indicates that the treatment provided had a fairly significant effect on enhancing the students' creative thinking abilities.

Table 6. Result of N-Gain Analysis Of Students Creative Thinking Skills

C**lass**	**N**	**N-Gain**	**Description**
Experiment	25	0.42	Medium

The N-Gain analysis for each indicator of creative thinking skills shows that all indicators fall into the medium category. The flexibility indicator has the highest N-Gain value of 0.50, followed by originality and sensitivity to problems, each with a value of 0.43. Fluency has an N-Gain value of 0.38, while elaboration has the lowest value of 0.33. These results indicate that the biodiesel production practice provides a fairly significant and balanced improvement across various aspects of students' creative thinking skills.

However, although all indicators of creative thinking skills increased, the degree of improvement varied. Flexibility improved the most, possibly because the practice allowed students to generate multiple strategies and solutions when making biodiesel, stimulating divergent thinking. In contrast, **elaboration** showed the lowest increase, which may be due to the higher cognitive demand required for developing ideas in detail. Students often struggled to expand their answers or provide detailed explanations within the limited practice time. A study by Qomariyah & Subekti (2021), similarly found that students faced challenges in elaborating ideas during science learning activities. Likewise, development of stem based e-learning on renewable energy topic Nazhifah & Wiyono (2023) reported that students were less confident when asked to elaborate on concepts in depth, especially

when teacher scaffolding was minimal. In addition, STEAM Activity on Biodiesel Production Khamhaengpol et al., (2022) how that procedural complexity in biodiesel production could hinder students' ability to refine and elaborate ideas in detail. These findings suggest that while hands-on practice strongly supports idea generation (flexibility, originality), more explicit strategies and time are needed to strengthen elaboration skills.

Table 7. Result of N-Gain Analysis of Each Indicator of Creative Thinking Skills

No.	Indicator	Number of Question	N-Gain	Category
1	Flexibility	2	0.50	Medium
2	Fluency	2	0.38	Medium
3	Originality	2	0.43	Medium
4	Elaboration	2	0.33	Medium
5	Sensitivity to Problem	2	0.43	Medium

Table 8 shows an effect size value of 1.84, indicating that the biodiesel production practice has a very large impact on improving students' creative thinking skills. This means that the activity successfully helped students develop their creative thinking abilities quite significantly.

Table 8. Effect Size

Class	N	Effect Size	Description
Experiment	25	1.84	Very Large

Beyond statistical results, several external factors may have influenced the outcomes. Student motivation, prior knowledge of energy concepts, and teacher guidance during practice sessions likely played important roles. For example, highly motivated students tended to explore biodiesel-making procedures more actively, which may explain why flexibility improved more than elaboration. The short two-week duration of practice might also have limited opportunities for detailed idea development. These factors align with findings from *Needs Analysis for the Development of Interactive Infographic Media Based on Discovery Learning on Renewable Energy Topics* Marita et al. (2025), which emphasized that resource availability, instructional design, and teacher readiness are critical for maximizing learning outcomes.

This study has some limitations, namely that it involved only one class without a comparison group, so the results cannot be generalized to other schools or classes. The absence of a control group also makes it difficult to rule out the influence of external factors completely. Furthermore, the two-week practice period is too short to produce significant long-term results. Therefore, further research should employ quasi-experimental designs with control groups, involve larger and more diverse samples, and extend the intervention duration to capture more comprehensive and sustainable effects.

4. CONCLUSION

Based on the results of the study, it can be concluded that the biodiesel production practice is effective in improving the creative thinking skills of eighth-grade students at Junior High School in Sleman. This improvement is supported by a significant difference between pretest and posttest scores, a medium category n-Gain value, and a very large effect size. All indicators of creative thinking skills showed improvement, with flexibility showing the highest increase and elaboration the lowest. These findings demonstrate that contextual, practice-based learning can encourage students to think more creatively and innovatively.

Beyond the statistical results, the study provides several practical implications. For teachers, biodiesel production practice can be integrated into science lessons as a discovery-based activity that connects theory with real-world applications. Careful planning is required to ensure student safety during experiments and to provide adequate resources such as equipment, materials, and supervision. For curriculum developers, embedding renewable energy practices in science learning can enrich the curriculum by fostering both conceptual understanding and 21st-century skills. For policymakers, support in the form of funding, teacher training, and provision of laboratory resources is essential to promote renewable energy education effectively in schools.

This study also has several limitations, particularly the use of only one class without a control group and the short two-week duration of the intervention, which restrict the generalizability and long-term interpretation of the findings. Therefore, further research is recommended to employ quasi-experimental designs with control groups, involve larger and more diverse samples, and extend the intervention duration to capture more comprehensive results. It would also be valuable to explore the long-term impact of biodiesel production practice on students' creative thinking skills and to investigate how this approach can be adapted across different schools and subject areas.

5. ACKNOWLEDGEMENT

The author would like to express sincere gratitude to Junior High School in Sleman for granting permission and providing facilities to carry out this research. Thanks are also extended to all eighth-grade students of class VIII A who participated enthusiastically in the biodiesel production practice. Additionally, the author expresses appreciation to the course lecturers who provided guidance and support throughout the research process. It is hoped that the results of this study will contribute positively to the development of science education, especially in teaching renewable energy.

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