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Evaluation of Critical Thinking Skills and Student Learning Outcomes through Demonstration and Experimental Learning on Photosynthesis

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ABSTRACT

Mastery of appropriate learning methods plays a crucial role in enhancing students understanding of photosynthesis concepts. The development of critical thinking skills is essential for enabling students to analyze information, construct logical arguments, and interpret scientific data effectively. This study aimed to evaluate the critical thinking skills and learning outcomes of eighth-grade students at Muhammadiyah Mamala Junior High School. The research involved two classes, namely class VIII-A and VIII-B. A quasi-experimental design was employed, where class VIII-A was taught using the demonstration method, while class VIII-B applied the experimental method. The research instruments included critical thinking worksheets, pre-test–post-test assessments to measure learning outcomes, affective observation sheets, and psychomotor assessment sheets. Data were analyzed using the Independent Sample t-test with SPSS v.20. The findings revealed that both instructional methods significantly improved students' learning outcomes and critical thinking skills. However, the experimental method showed a slightly higher impact compared to the demonstration method. This novelty indicates that both demonstration and experimental approaches are effective in promoting active learning and improving students' cognitive, affective, and psychomotor domains. Therefore, teachers are encouraged to integrate these methods into science instruction to enhance students overall learning performance.

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1. INTRODUCTION

21st-century education demands mastery of essential skills, one of which is critical thinking. Critical thinking plays a fundamental role in enabling students to analyze information, evaluate evidence, and solve problems logically and systematically. In the context of science education, these skills are indispensable, as science is not merely the accumulation of facts but a process of inquiry that requires reasoning, interpretation, and decision-making. Therefore, fostering critical thinking skills is a central objective in science learning to prepare students for real-world challenges. In addition to critical thinking, learning outcomes serve as an important indicator of the success of the educational process. Learning outcomes reflect the extent to which students understand, master, and are able to apply the material taught in meaningful contexts (Putra et al., 2025). Optimal learning outcomes are generally achieved when students are actively involved in the learning process and are given opportunities to explore concepts independently. Thus, the development of critical thinking skills and the achievement of high learning outcomes are closely interconnected.

However, in practice, the learning process in many schools is still dominated by teacher-centered approaches, particularly the lecture method. This approach often limits student participation, making them passive recipients of information rather than active learners. As a result, students tend to have difficulty developing higher-order thinking skills, including critical thinking, which ultimately affects their learning outcomes (Sembiring, 2025). This issue is also observed in Muhammadiyah Mamala Junior High School, where students show low engagement during lessons. The problem becomes more evident in the teaching of photosynthesis, a topic that is inherently abstract and complex. Photosynthesis involves biochemical processes that cannot be directly observed with the naked eye, making it difficult for students to fully comprehend through verbal explanations alone. Consequently, students often struggle to understand key concepts, leading to misconceptions and low academic performance. This indicates the need for instructional strategies that can bridge the gap between abstract concepts and concrete understanding. To address this challenge, learning methods that emphasize active student involvement are required. Demonstration and experimental methods are considered effective alternatives because they provide concrete learning experiences. The demonstration method allows students to observe processes directly under teacher guidance, helping them visualize abstract concepts. On the other hand, the experimental method engages students in hands-on activities, enabling them to investigate phenomena, formulate hypotheses, and draw conclusions independently. Both methods are known to significantly enhance students' critical thinking skills and learning outcomes (Fransiska, 2024; Mokodompit et al., 2025; El-Islami et al., 2025).

Furthermore, the use of experimental methods is closely aligned with the principles of inquiry-based learning, which emphasizes student exploration and discovery. Through experimentation, students are encouraged to ask questions, test ideas, and reflect on their findings. This process not only deepens conceptual understanding but also strengthens scientific attitudes such as curiosity, objectivity, and open-mindedness. Meanwhile, demonstration methods can serve as an initial step to build foundational understanding before students engage in more complex investigative activities. In addition, integrating appropriate learning methods in science instruction can create a more engaging and meaningful learning environment. When students are actively involved, they are more motivated to learn and better able to retain information. Active learning also facilitates collaboration and communication among students, which are essential competencies in 21st-century education. Therefore, selecting suitable instructional methods is crucial for improving both the quality of the learning process and student achievement.

Although previous studies have shown that both demonstration and experimental methods are effective in improving student engagement and understanding, there is still limited research that directly compares the effectiveness of these two methods, particularly in the context of photosynthesis learning at Muhammadiyah Mamala Junior High School. Each method has its own strengths and limitations, and their effectiveness may vary depending on the characteristics of the material and learners. Therefore, this study aims to evaluate and compare the critical thinking skills and learning outcomes of eighth-grade students who are taught using demonstration and experimental methods. By conducting this research, it is expected that empirical evidence can be obtained regarding the most effective method for teaching photosynthesis. The findings of this study are expected to provide valuable insights for teachers in selecting appropriate instructional strategies that align with the nature of the subject matter and the needs of students, ultimately contributing to the improvement of science education quality.

2. MATERIALS AND METHOD

This research was conducted from April 15 to May 15, 2025, at Muhammadiyah Mamala Junior High School (MMJHS), Leihitu District, Central Maluku Regency, Maluku Province, Indonesia. The research used a quantitative approach with a quasi-experimental design involving two classes as treatment groups, namely class VIII-A taught using the demonstration method and class VIII-B taught using the experimental method. The research population consisted of 67 class VIII students, and the sample was determined using a purposive sampling technique, with 22 students per class. The instruments used in this study included student activity observation sheets, a learning outcome test in the form of 20 multiple-choice questions arranged based on photosynthesis material, and Student Worksheets (LKPD) to assess critical thinking skills.

Documentation in the form of activity photos and school archives were also used to complete the research data. The research procedure began with a pre-test given to both classes to determine students' initial abilities. Next, class VIII-A received learning using the demonstration method, while class VIII-B received learning using the experimental method. During the learning process, researchers conducted observations to see student activities. After the treatment was given, both classes were given a post-test aimed at measuring the improvement in learning outcomes. Assessment of critical thinking skills was carried out through analysis of LKPDs worked on by students during learning activities. The research data were analyzed quantitatively using the SPSS v.20 software. The normality test was used to determine the distribution of the data, then the differences in critical thinking skills and learning outcomes between the two groups were analyzed using the Independent Sample t-Test at a significance level of 0.05.

3. RESULTS AND DISCUSSION

3.1 Critical thinking

Student critical thinking data during the learning process by applying the demonstration method and the experimental method through Student Worksheets, which are assessed based on the student critical thinking assessment rubric during the learning process can be seen in **Table 1**.

Table 1. Frequency distribution of students' critical thinking at MMJHS.

Demonstration Class			Experimental Class		
Interval	Freq.	Relative Freq. (%)	Interval	Freq.	Relative Freq. (%)
<55	0	0	<55	0	0
55–69	5	22.73	55–69	0	0
70–84	13	59.09	70–84	12	54.55
85–100	4	18.18	85–100	10	45.45
Total	22	100	Total	22	100

In accordance with **Table 1**, frequency distribution of students' critical thinking skills in the demonstration class and the experimental class grouped into four categories, namely: need guidance (<55), sufficient (55–69), good (70–84), and very good (85–100). In the demonstration class (22 students), there were no students in the need guidance category. A total of 5 students (22.73%) were in the sufficient category, 13 students (59.09%) in the good category, and 4 students (18.18%) in the very good category. On the other hand, the experimental class also consisted of 22 students and showed higher results: no students were in the need guidance or sufficient category, 12 students (54.55%) were in the good category, and 10 students (45.45%) were in the very good.

3.2 Learning outcomes

The initial test was conducted to determine students initial understanding and abilities of the concept of photosynthesis before participating in the learning process. This test was administered at the beginning of the session to two classes that would be taught using different learning methods: demonstration and experimentation. The results of the initial test indicate that students' initial abilities are still relatively low. This can be seen in **Table 2**, which presents the frequency distribution of the average pre-test scores for both classes.

Table 2. Frequency distribution of pre-test demonstration and experiment class at MMJHS.

Demonstration Class			Experimental Class		
Interval	Freq.	Relative Freq. (%)	Interval	Freq.	Relative Freq. (%)
<55	17	77.27	<55	15	68
55–69	4	18.18	55–69	6	27
70–84	1	4.55	70–84	1	5
85–100	0	0	85–100	0	0
Total	22	100	Total	22	100

Based on **Table 2**, it can be seen that before the learning was implemented, both the demonstration class and the experimental class had a large number of students with low pre-test results. In the demonstration class, as many as 77.27% of students were in the <55 category (need guidance), while in the experimental class as many as 68% of students were also in the same category. Only a few students reached the good category (70–84) in both classes, namely 4.55% in the demonstration class and 5% in the experimental class. No students reached the very good category (85–100) in both classes. Assessment during the learning process is carried out based on three aspects: cognitive, affective, and psychomotor. Cognitive assessment is carried out through pre-test and post-test questions. Meanwhile, affective and psychomotor aspects are directly assessed during the assessment process.

3.3 Students Cognitive Abilities

Data on student's cognitive abilities in the appendix during the learning process by applying the Demonstration and Experimental learning methods and can be seen through the pre-test and post-test percentages can be seen in the frequency distribution of student achievement in **Table 3**.

Table 3. Frequency distribution of pre-test and post-test as cognitive aspects of the demonstration class at MMJHS.

Pre-test			Post-test		
Interval	Freq.	Relative Freq. (%)	Interval	Freq.	Relative Freq. (%)
<55	17	77.27	<55	0	0
55–69	4	18.18	55–69	5	22.73
70–84	1	4.55	70–84	14	63.64
85–100	0	0	85–100	3	13.64
Total	22	100	Total	22	100

Derived on **Table 3,** it can be seen that before the learning was implemented, both the demonstration class and the experimental class had a large number of students with low pre-test results. In the demonstration class, as many as 77.27% of students were in the <55 category (need guidance), while in the experimental class as many as 68% of students were also in the same category. Only a few students reached the good category (70–84) in both classes, namely 4.55%

in the demonstration class and 5% in the experimental class. No students reached the very good category (85–100) in either class. These data indicate that at the beginning of learning, students' understanding of photosynthesis material was still low and relatively even in both classes. Therefore, appropriate learning strategies are needed, such as demonstration and experimental methods, to significantly improve student learning outcomes.

Informed by **Table 4**, pre-test results show that the majority of students in the experimental class were in the category needing guidance (<55) at 68%, and no students reached the very good category. After learning with the experimental method was implemented, there was a significant improvement. There were no more students in the <55 and 55–69 categories, while 68% of students reached the very good category (85-100), and 32% were in the good category (70–84). This indicates that the experimental method is very effective in improving student learning outcomes.

Table 4. Frequency distribution of pre-test and post-test as cognitive aspects of the experimental class at MMJHS.

	Pre-test			Post-test	
Interval	Freq.	Relative Freq. (%)	Interval	Freq.	Relative Freq. (%)
<55	15	68	<55	0	0
55–69	6	27	55–69	0	0
70–84	1	5	70–84	7	32
85–100	0	0	85–100	15	68
Total	22	100	Total	22	100

3.4 Students Affective Abilities

The affective aspect assessment data was obtained through an observation sheet used to assess students abilities which include aspects of mutual cooperation, responsibility, and social concern. The frequency distribution of students' achievement in the affective aspect is shown in **Table 5**.

Table5. Frequency distribution of affective aspects of the demonstration and experimental class at MMJHS.

Demonstration Class			Experimental Class		
Interval	Freq.	Relative Freq. (%)	Interval	Freq.	Relative Freq. (%)
<55	0	0	<55	0	0
55–69	0	0	55–69	0	0
70–84	15	68	70–84	13	59
85–100	7	32	85–100	9	41
Total	22	100	Total	22	100

The data in the table shows that the affective aspects of students in both classes are in the good to very good category. In the demonstration class, 68% of students are in the good category (70–84) and 32% are in the very good category (85–100). Meanwhile, in the experimental class, 59% of students are in the good category and 41% are in the very good category. These results indicate that both learning methods are able to shape positive attitudes in students, with a higher tendency in the experimental class in the very good category.

3.5 Students Psychomotor Abilities

Based on the psychomotor assessment data obtained from the demonstration and experimental methods, the assessment included communication skills, problem-solving skills, and accuracy in creating photosynthesis flowcharts. The frequency distribution of students can be seen in **Table 6**.

Table 6. Frequency distribution of psychomotor aspects of the demonstration and experiment class at MMJHS.

Demonstration Class			Experimental Class		
Interval	Freq.	Relative Freq. (%)	Interval	Freq.	Relative Freq. (%)
<55	0	0	<55	0	0
55–69	0	0	55–69	0	0
70–84	15	68	70–84	11	50
85–100	7	32	85–100	11	50
Total	22	100	Total	22	100

On the basis of **Table 6**, it shows that all students in both classes achieved good to excellent psychomotor skills. In the demonstration class, 68% of students were in the good category (70–84) and 32% in the excellent category (85–100). Meanwhile, in the experimental class, the percentage of students in the good and excellent categories was 50% each. This reflects that both learning methods successfully developed students' psychomotor skills, with a balanced distribution in the experimental class. The results of the study showed that students' critical thinking skills in the experimental class were higher than in the demonstration class. This improvement is related to the characteristics of the experimental method, which places students as active subjects through observation, hypothesis formulation, experiment implementation, data analysis, and conclusion drawing. This direct involvement encourages students to develop analytical, interpretation, inference, and evaluation skills, in accordance with the characteristics of critical thinking (Octaviani, 2024; Faizah, 2025). In photosynthesis learning, experimental activities such as observing changes in Hydrilla plants provide real-life learning experiences that encourage students to ask questions, assess evidence, and connect results to concepts. This finding aligns with previous research that suggests that experiment-based learning can improve students' higher-order thinking skills and scientific argumentation abilities (Handayani et al., 2023; Setyowati, 2021). In contrast, the demonstration method places students in the role of observers. While effective in simplifying concepts, this approach provides less room for students to build understanding through direct experience, thus suboptimal critical thinking development (Yuliana et al., 2025).

This aligns with constructivism theory, which emphasizes that meaningful learning occurs when students engage directly with objects or phenomena (Alfadilah, 2025). Therefore, research findings indicate that the experimental method is more effective in developing critical thinking across all aspects, including interpretation, analysis, inference, evaluation, explanation, and self-regulation. Consequently, science learning is recommended to utilize the experimental method or combine it with demonstrations to achieve optimal development of higher-order thinking skills. Student learning outcomes in the experimental class also showed higher improvement compared to the demonstration class. Active student involvement during the experiment, such as collecting data, connecting results to theory, and verifying findings, helped them build a stronger understanding in accordance with the principles of constructivism (Mariyono, 2024). Previous research has shown that learning through experiments can reduce misconceptions, improve conceptual understanding, and strengthen analytical and application skills in photosynthesis (Lestari et al., 2021; Hanisu et al., 2025). The experimental process, which involves trial and error, also enriches the scientific experience, thus improving the cognitive, affective, and psychomotor domains (Ningsih et al., 2024; Listari et al., 2025).

Demonstration methods are still useful for helping students understand certain procedures or processes, but they do not provide the same in-depth learning experience as experiments (Wilani et al., 2025). Therefore, a combination of demonstrations and experiments can be a complementary approach in science learning (Purwanti et al., 2024). Overall, experimental methods have been shown to contribute significantly to learning outcomes because they allow students to apply concepts, analyze data, evaluate findings, and draw conclusions independently.

4. CONCLUSION

Both the demonstration method and the experimental method have a positive impact on learning photosynthesis, particularly in helping students understand fundamental concepts and biological processes. However, the experimental method shows more optimal results in improving students' critical thinking skills, as it allows them to actively engage in the scientific process through observation, hypothesis testing, and drawing conclusions based on real data. Learning outcomes are also more pronounced in classes that apply the experimental method, since students are directly involved in data collection, analysis, and validation, leading to a deeper understanding of photosynthesis. Nevertheless, the demonstration method still plays an important role, especially in providing clear examples of correct procedures, explaining practical steps, and introducing initial concepts before students conduct independent activities. Overall, the experimental method can be used as the primary approach in teaching photosynthesis, while the demonstration method serves as a supportive strategy to strengthen foundational understanding and prepare students for experimental work.

AUTHORS CONTRIBUTION

IFW and PMP designed and conducted the research, analysed and interpretation the data and wrote the draft of the manuscript.

CONFLICT OF INTEREST

The authors declare no conflicts of interest and take full responsibility for the content of the article, including any implications of AI-generated art.

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