

Effect of Eco-Friendly Wind Turbine Teaching Aids on Elementary Students' Energy Conceptual Understanding

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Abstract

This study examines the effect of environmentally friendly science teaching aids in the form of a windmill integrated into experimental learning on third-grade students' conceptual understanding of energy in Madrasah Ibtidaiyah. A quantitative quasi-experimental method with a nonequivalent control group design was employed. The sample consisted of 46 students selected through purposive sampling, including 24 in the experimental group and 22 in the control group. The experimental group received experimental learning supported by windmill-based teaching aids made from recycled materials, while the control group received experimental learning without teaching aids. Data were collected using a validated multiple-choice test measuring conceptual understanding across cognitive levels C1–C4. The instrument demonstrated acceptable reliability (Cronbach's $\alpha \geq 0.70$). Data analysis included descriptive statistics, Shapiro–Wilk normality test, Levene's homogeneity test, independent samples t-test, and N-Gain analysis. The results showed no significant difference in pretest scores, indicating equivalent baseline understanding. However, posttest results revealed a significant difference favoring the experimental group. The normalized gain was higher in the experimental group (59.21%, moderate–high) compared to the control group (11.22%, low). The effect size was very large (Cohen's $d = 3.47$), indicating a strong practical impact. These findings demonstrate that integrating environmentally friendly windmill-based teaching aids into experimental learning significantly improves students' conceptual understanding of energy.

Keywords

Science Teaching Aids, Experimental Learning, Conceptual Understanding, Energy, Islamic Elementary School.



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INTRODUCTION

Science education at the elementary level plays a crucial role in developing students' scientific literacy, particularly their ability to understand scientific concepts meaningfully (Hattie, 2009; Ormrod, 2020; Slavin, 2018). Conceptual understanding is essential because it enables students to explain phenomena, apply knowledge in different contexts, and engage in higher-order thinking processes rather than merely memorizing facts (Anderson & Krathwohl, 2001; Ormrod, 2020). In science learning, especially at the Madrasah Ibtidaiyah level, students are expected to construct understanding across cognitive levels ranging from remembering to analyzing (C1–C4) as outlined in the revised taxonomy by Anderson and Krathwohl (2001). However, many scientific concepts, such as energy, are abstract and involve processes that cannot be directly observed, making them difficult for students to comprehend without appropriate instructional support (Widodo & Riandi, 2013; Zacharia & Olympiou, 2011).

At the research location, MI Darussalam, preliminary observations revealed that students' conceptual understanding of energy remains relatively low. The average science score of third-grade students was 68, below the minimum mastery criterion (KKM) of 75. Furthermore, classroom observations indicated that students experienced difficulty explaining energy transformation processes conceptually and tended to rely on rote memorization. This suggests that students have not yet developed a deep understanding of scientific concepts, highlighting a gap between expected and actual learning outcomes (Ormrod, 2020; Slavin, 2018).

In recent years, studies on conceptual understanding in science education have emphasized the importance of active and student-centered learning approaches. Research indicates that experimental and inquiry-based learning can significantly improve students' conceptual understanding by engaging them in hands-on activities and encouraging knowledge construction (Kuhlthau et al., 2015; Savery, 2015). Subella and Hakim (2023) found that the use of teaching aids enhances students' conceptual mastery in science learning. Similarly, Fitriana and Prayogi (2023) demonstrated that environmentally friendly science teaching aids in the form of windmills made from recycled materials can support both conceptual understanding and environmental awareness. Other studies also highlight that meaningful learning occurs when students interact directly with learning materials and phenomena (Piaget, 1972; Türkmen, 2006; Yager, 2000).

However, despite these findings, several limitations remain. Many previous studies tend to examine experimental learning and instructional media separately, without integrating both approaches into

a unified learning design. In addition, most studies focus on general learning outcomes rather than specifically measuring conceptual understanding across cognitive levels (Anderson & Krathwohl, 2001; Widodo & Riandi, 2013). Empirical studies that quantitatively analyze learning improvement using normalized gain and effect size within quasi-experimental designs are still limited, particularly in the context of Madrasah Ibtidaiyah (Cohen, 1988; Creswell & Creswell, 2018).

Based on these limitations, a clear research gap can be identified: there is a lack of studies that investigate the integration of environmentally friendly science teaching aids in the form of windmills within experimental learning to improve students' conceptual understanding of energy using rigorous quantitative analysis. This gap highlights the need for research that not only examines learning outcomes but also measures the magnitude of conceptual improvement and its practical significance (Fraenkel et al., 2019; Hake, 1998).

The use of environmentally friendly science teaching aids in the form of windmills has both theoretical and practical potential. Theoretically, it aligns with constructivist learning theory, which emphasizes that knowledge is actively constructed through interaction with concrete objects and real-world contexts (Piaget, 1972; Yager, 2000). Practically, these teaching aids provide accessible and low-cost alternatives for schools with limited laboratory facilities while simultaneously promoting environmental awareness (Fitriana silvana, 2023; Suryawati et al., 2010). By integrating environmentally friendly science teaching aids in the form of windmills into experimental learning, students can observe, manipulate, and analyze scientific phenomena more directly, thereby facilitating deeper conceptual understanding (Susi Subella, Lukman Hakim, 2023; Zacharia & Olympiou, 2011).

The novelty of this research lies in the integration of environmentally friendly science teaching aids in the form of windmills within experimental learning and the comprehensive measurement of conceptual understanding using normalized gain and effect size analysis. Unlike previous studies, this research focuses specifically on conceptual understanding across cognitive levels (C1–C4) and provides quantitative evidence of both statistical and practical significance within a quasi-experimental framework in Madrasah Ibtidaiyah settings (Cohen, 1988; Hake, 1998).

Therefore, this study aims to examine the effect of integrating environmentally friendly science teaching aids in the form of windmills into experimental learning on third-grade students' conceptual understanding of energy.

METHOD

This take a look at employed a quantitative technique the use of a quasi-experimental method with a nonequivalent manage group design. The research was carried out at MI Darussalam from January to February 2026, sooner or later of the second semester of the 2025/2026 educational year. The population consisted of 93 third-grade college students, and 46 students were decided on through purposive sampling, comprising 24 students within the experimental institution (class III C) and 22 students in the manipulate organization (class III B). The experimental group received experimental gaining knowledge of supported via environmentally friendly science teaching aids inside the shape of a windmill, even as the manipulate organization received experimental studying with out coaching aids. The established variable of this have a look at was college students' conceptual know-how of power, measured across cognitive ranges C1–C4 primarily based at the revised Bloom's Taxonomy.

Data acquisition involved the deployment of a 20-item, multiple-choice assessment meticulously crafted to evaluate students' conceptual grasp of energy principles. The validity of this instrument was established through the rigorous review process undertaken by subject matter experts specializing in science education, alongside an educator from a Madrasah Ibtidaiyah. Reliability assessments, employing Cronbach's Alpha, produced a coefficient of $\alpha = 0.82$, which signifies a robust level of internal consistency within the instrument. The subsequent data analysis encompassed descriptive statistical techniques for summarizing score distributions, the Shapiro–Wilk test to ascertain data normality, Levene's test to assess the homogeneity of variances, and an independent samples t-test to investigate intergroup disparities in both pre- and post-intervention performance measures. Moreover, normalized gain (N-gain) analysis was implemented to quantitatively gauge the significance of the observed conceptual advancements among the student cohort.

The pedagogically focused sustainable resources for science instruction featured in this investigation, specifically a wind turbine model, were fabricated utilizing repurposed and readily procurable components, including polymeric receptacles, cardstock, elastic closures, and formerly utilized vessels. The primary objective in designing these instructional implements was to elucidate fundamental energy principles, encompassing both the conversion and transmission of energy, through practical, experiential engagement. As an illustrative instance, a rudimentary apparatus, assembled from a plastic bottle and elastic elements, was employed to explicate the dynamic

interplay between kinetic and potential energy states. The deployment of such materials facilitated direct student observation and manipulation of scientific phenomena, consequently fostering robust conceptual comprehension whilst simultaneously cultivating an appreciation for environmental stewardship.

FINDINGS AND DISCUSSION

Findings

Descriptive Statistics

Descriptive statistics were used to summarize the distribution of students' scores before and after the treatment. As shown in Table 1, the mean pretest score of the experimental group was 79.79, slightly higher than that of the control group (75.91). This indicates that the experimental group had a relatively better initial understanding. Nevertheless, the difference was not considerable, suggesting that both groups started from a relatively comparable baseline.

Table 1. Descriptive Statistics

	N	Range	Minimum	Maximum	Mean	Std. Deviation
pretest Eksperimen	24	20	70	90	79.79	5.610
posttest Eksperimen	24	20	80	100	92.50	5.517
pretest Kontrol	22	25	60	85	75.91	5.903
posttest kontrol	22	15	70	85	79.09	3.975
Valid N (listwise)	22					

Source: SPSS 16

Subsequent to the investigation, the experimental cohort evinced a post-intervention mean score of 92.50, a notable elevation from their pre-intervention baseline. Concurrently, the control group attained a mean score of 79.09. While both participant groups exhibited demonstrable scholastic advancement, the magnitude of improvement observed in the experimental group significantly surpassed that of the control group. Specifically, the experimental group registered a mean increment of 12.71 score points, in stark contrast to the mere 3.18 score point augmentation observed in the control group. This pronounced disparity robustly implies that the integration of ecologically sound pedagogical resources, within the framework of experiential scientific inquiry, yielded a more efficacious enhancement of students' conceptual grasp of the subject matter. Consequently, the statistical evidence presented in Table 1 unequivocally demonstrates the superior learning achievements of the experimental group relative to the control group following the implementation of the pedagogical intervention.

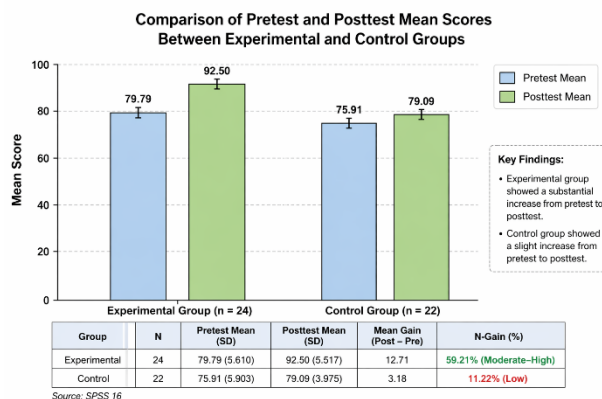


Figure 1. Comparison of Pretest and Posttest Mean Scores Between Experimental and Control Groups

Figure 1 delineates a comparative analysis of the pretest and posttest average scores across both the experimental and control cohorts. Observed within the experimental cohort was a more pronounced augmentation in mean scores subsequent to the intervention, in contrast to the control group. Furthermore, the graphical representation encompasses the mean gain and the Net Gain percentage, thereby substantiating the enhanced efficacy of experimental learning, fortified by ecologically sustainable scientific instructional materials, in cultivating students' conceptual grasp of energy.

Normality Test

The normality of the data was assessed using the Shapiro–Wilk test, and the results are presented in Table 2. The significance values for all datasets (pretest and posttest in both groups) were below .05, indicating that the data were not normally distributed.

Table 2. Normality test
Tests of Normality

Kelas		Kolmogorov-Smirnov ^a			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Hasil Belajar	Pretest Eksperimen	.262	24	.000	.870	24	.005
	Posttest Eksperimen	.254	24	.000	.854	24	.003
	Pretest Kontrol	.256	22	.001	.852	22	.004
	Posttest Kontrol	.272	22	.000	.862	22	.006

Source: SPSS 16

Notwithstanding the Shapiro–Wilk test revealing a departure from normal distribution in the data ($p < .05$), the independent samples t-test was nevertheless utilized. This course of action was justified by the t-test's established resilience to moderate deviations from normality, especially when

group sample sizes are comparably sized and each surpasses 20 participants. The current investigation's sample sizes for the experimental ($n = 24$) and control groups ($n = 22$) align with this requirement.

Furthermore, the condition of equal variances between groups was upheld ($p > .05$), providing additional rationale for employing parametric statistical methods (Creswell & Creswell, 2018; Field, 2013). Consequently, despite the observed non-normality, the application of the independent samples t-test was deemed suitable.

Homogeneity Test

The homogeneity of variance was tested using Levene's test, as shown in Table 3. The significance value obtained was 0.373 ($p > .05$), indicating that the variances of the experimental and control groups were homogeneous

Table 3. Homogeneity test

	Levene Statistic	df1	df2	Sig.
Result Based on Mean	.812	1	44	.373
Based on Median	.930	1	44	.340
Based on Median and with adjusted df	.930	1	43.720	.340
Based on trimmed mean	.913	1	44	.344

Source: SPSS 16

Table 3. This table displays the outcomes of Levene's test for the equality of variances, a statistical procedure employed to ascertain if the variances of the two groups are equivalent prior to executing the independent samples t-test. The significance values (Sig.) for all indicators are greater than 0.05, specifically .373, .340, .340, and .344. This means that the assumption of equal variance was met, allowing the use of the independent samples t-test for hypothesis testing.

Hypothesis Testing (t-Test)

To test the research hypothesis, an independent samples t-test was conducted, and the results are presented in Table 4.

Table 4. Independent Samples t-Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Result	Equal variances assumed	.812	.373	11.813	44	.000	14.451	1.223	11.985	16.916
	Equal variances not assumed			11.853	43.994	.000	14.451	1.219	11.994	16.908

Source: SPSS 16

The accompanying table displays the outcomes of an independent samples t-test, which was conducted to ascertain differences in posttest mean scores between an experimental cohort and a control group. Prior to interpreting the t-test findings, Levene's test for the homogeneity of variances was assessed. The reported significance value (Sig.) for Levene's test was 0.373. As this value exceeds the conventional alpha level of 0.05, the prerequisite of equal variances is satisfied. Consequently, the statistical data presented in the row labeled "Equal variances assumed" is appropriate for interpretation.

Analysis of the t-test results, under the assumption of equal variances, revealed a significance value (Sig. 2-tailed) of 0.000. This outcome is below the 0.05 threshold, leading to the rejection of the null hypothesis (Ho) and the acceptance of the alternative hypothesis (Ha). This finding signifies a statistically significant disparity in the posttest mean scores observed between the experimental group and the control group. The magnitude of this difference between the means is 14.451 points, with a 95% confidence interval spanning from 11.985 to 16.916. This finding indicates that the posttest scores of the experimental group are significantly higher than those of the control group, showing that the use of environmentally friendly windmill teaching aids in experimental learning has a significant positive effect on students' conceptual understanding of energy.

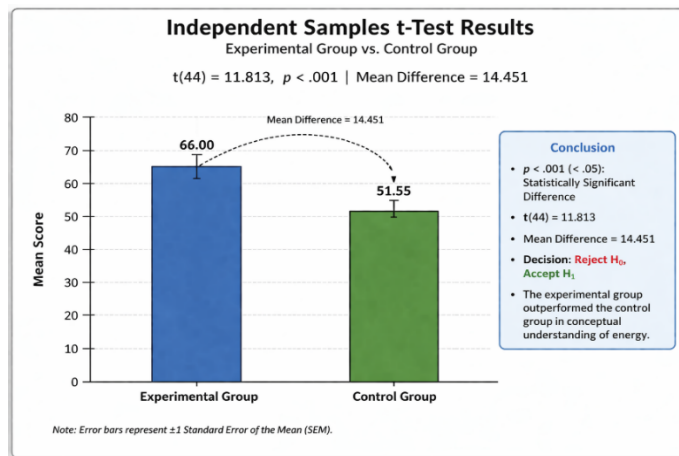


Figure 2. Mean Difference Between Experimental and Control Groups

Figure 2 visually presents the disparity in mean posttest scores between the experimental and control groups, as determined by independent samples t-test statistical analysis. The experimental group evinced superior average scores relative to the control group, with a quantified mean difference of 14.451 points. The computed significance level ($p < .001$) unequivocally affirms the statistical robustness of the divergence between the two groups. This empirical outcome underscores the pronounced impact of integrating environmentally benign windmill pedagogical tools within the framework of experimental learning had a significant positive effect on students' conceptual understanding of energy.

Learning Improvement (N-Gain Analysis)

The improvement in students' conceptual understanding was further analyzed using N-Gain, and the results are presented in Table 5

Table 5. N-Gain Analysis

Class			Statistic	Std. Error	
N_GainPersen	Eksperimen	Mean	59.21	6.619	
		95% Confidence Interval for Mean	Lower Bound	45.30	
			Upper Bound	73.12	
		5% Trimmed Mean	60.23		
		Median	66.67		
		Variance	832.521		
		Std. Deviation	28.853		
		Minimum	0		
		Maximum	100		
		Range	100		
		Interquartile Range	42		
		Skewness	-.099	.524	
		Kurtosis	-.585	1.014	
		Control	Control	Mean	11.22
95% Confidence Interval for Mean	Lower Bound			4.97	
	Upper Bound			17.48	
5% Trimmed Mean	9.80				
Median	.00				
Variance	198.852				
Std. Deviation	14.101				
Minimum	0				
Maximum	50				
Range	50				
Interquartile Range	21				
Skewness	1.060			.491	
Kurtosis	.799			.953	

Source: SPSS 16

The experimental group achieved a mean N-Gain score of 59.21%, which falls into the moderate–high category, while the control group obtained only 11.22%, categorized as low. This indicates that the experimental group experienced a substantially greater improvement in

conceptual understanding compared to the control group.

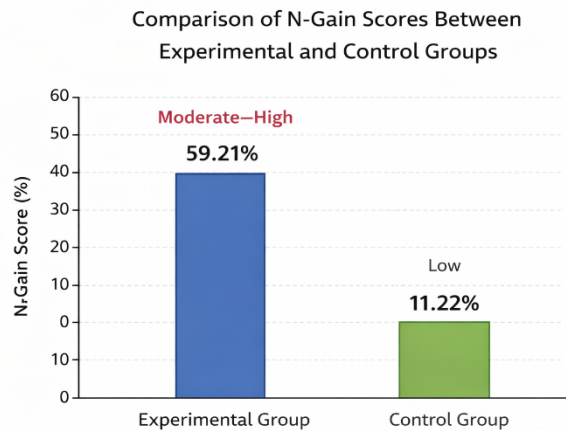


Figure 3. N-Gain Comparison Between Experimental and Control Groups

Figure 3 displays a comparative analysis of N-Gain scores for both the experimental and control cohorts. The experimental group registered an N-Gain score of 59.21%, which falls within the moderate-to-high range. In contrast, the control group achieved an N-Gain score of 11.22%, classified as low. These results suggest that the integration of eco-friendly windmill teaching apparatuses in the experimental learning setting was more successful in enhancing students' grasp of energy concepts when contrasted with learning experiences that did not involve such aids.

Discussion

This investigation sought to elucidate the influence of employing ecofriendly scientific pedagogical instruments, specifically a windmill, within an experimental learning paradigm on the students' grasp of energy-related concepts. The findings suggest that participants who engaged with these sustainable teaching aids exhibited superior post-intervention assessment scores and more substantial learning improvements when contrasted with a control group that did not utilize such aids. Consequently, the research's primary objective has been demonstrably met, substantiating that the incorporation of teaching aids in experiential education significantly augments conceptual comprehension (Sari & Sumarni, 2022; Susi Subella, Lukman Hakim, 2023).

The results indicate that despite the experimental cohort exhibiting elevated pretest scores relative to the control cohort, both groups' initial performance levels remained commensurable, thereby ensuring their appropriateness for subsequent inferential statistical examinations. Crucially, a demonstrably augmented disparity in learning advancements was observed post-intervention. The considerable mean variance in posttest scores (14.451), coupled with a moderate-to-high normalized gain (N-Gain = 59.21%) and an exceptionally large effect size (Cohen's $d = 3.47$),

collectively signify not merely statistical significance but also profound practical applicability. This suggests that the implemented pedagogical strategy exerted a considerable influence on students' academic acquisition. The marked enhancement observed within the experimental group underscores the pivotal role of employing eco-conscious scientific instructional resources, exemplified by a windmill model that facilitates experiential, applied, and contextually relevant learning, in fostering students' comprehension of abstract notions such as energy transformation. (Nisa & Sudarmin, 2016; Zacharia & Olympiou, 2011).

According to Piaget (1972), knowledge is actively constructed through interaction with the environment, which is a central principle of constructivist learning theory. In line with this, Slavin (2018) explains that meaningful learning occurs when students actively participate in the learning process rather than passively receiving information. In this study, environmentally friendly science teaching aids in the form of a windmill functioned as concrete learning media that enabled students to observe and manipulate energy processes directly, thereby supporting experiential learning as also emphasized by Dahar (2011).



Figure 4. Students' Activities in Constructing and Testing Environmentally Friendly Science Teaching Aids in the form of a Windmill.

Additionally, Anderson and Krathwohl (2001) state that cognitive learning advances from basic thinking skills (remembering and understanding) to advanced thinking skills (applying and analyzing). The combination of experimental activities with teaching tools in this study allowed students to engage in predicting, observing, and analyzing, thus fostering advanced thinking skills (C3–C4) (Savery, 2015; Widodo & Riandi, 2013).

Moreover, Hake (1998) emphasizes that interactive engagement is essential for enhancing students' conceptual understanding. The relatively high N-Gain achieved in the experimental group reflects how effective active learning environments are in promoting conceptual change and deeper understanding (Kang & Keinonen, 2018; Wieman & Perkins, 2005). The findings of this study align with those of Subella and Hakim (2023), who identified that using teaching tools significantly

enhances students' conceptual mastery in science learning. Likewise, Fitriana and Prayogi (2023) found that teaching aids made from recycled materials boost both conceptual understanding and environmental awareness among elementary students.

In addition, Lestari and Widodo (2022) showed that experimental learning enhances conceptual understanding through hands-on activities. However, unlike previous studies that typically examine teaching aids and experimental learning separately, this study integrates both approaches into a unified instructional design by incorporating environmentally friendly science teaching aids in the form of a windmill into experimental learning. Furthermore, prior studies often focus only on learning outcomes without measuring the magnitude of improvement. This study extends previous research by incorporating N-Gain and effect size (Cohen's *d*) analyses, thereby providing stronger empirical evidence of both statistical and practical significance (Cohen, 1988; Hake, 1998).

The novelty of this study lies in three main aspects. First, it integrates environmentally friendly science teaching aids in the form of a windmill with hands-on experimental learning into a single instructional model, which has rarely been explored. Second, it measures conceptual understanding across cognitive levels (C1–C4), providing a more comprehensive assessment of learning outcomes (Anderson & Krathwohl, 2001). Third, it employs advanced quantitative analyses, including N-Gain and effect size, to measure both learning improvement and its practical significance (Creswell & Creswell, 2018; Hake, 1998). This positions the study as a significant contribution to elementary science education research, particularly within the context of Madrasah Ibtidaiyah.

Consequently, the present investigation corroborates prior research while simultaneously broadening its scope by employing a more exhaustive analytical methodology pertinent to the Madrasah Ibtidaiyah setting. The outcomes carry ramifications of both a theoretical and applied nature. From a theoretical standpoint, this research substantiates constructivist learning principles by illustrating that the acquisition of knowledge through direct engagement with tangible and relevant resources fosters a deeper grasp of concepts (Piaget, 1972; Yager, 2000). Practically, the use of environmentally friendly science teaching aids in the form of a windmill offers an effective and low-cost alternative for science instruction, particularly in schools with limited laboratory facilities, while also promoting environmental awareness (Fitriana silvana, 2023; Suryawati et al., 2010). For

teachers, this approach can be used to create more engaging, meaningful, and student-centered learning experiences (Slavin, 2018; Uno, 2016).

Despite its contributions, this study has several limitations. First, the sample size was relatively small and limited to one Madrasah Ibtidaiyah, which may affect the generalizability of the findings. Second, the quasi-experimental design did not involve random assignment, which may introduce potential bias (Creswell & Creswell, 2018; Fraenkel et al., 2019). Third, this study only examined short-term conceptual understanding and did not investigate long-term retention. Additionally, external factors such as student motivation and novelty effects may have influenced the results (Uno, 2016).

Future research is recommended to involve larger and more diverse samples across different schools to improve generalizability. Researchers are also encouraged to employ randomized experimental designs to enhance internal validity. Furthermore, longitudinal studies are needed to examine the long-term retention of conceptual understanding (Creswell & Creswell, 2018; Fraenkel et al., 2019).

Further studies may also explore additional variables such as scientific literacy, critical thinking skills, and environmental attitudes to provide a more comprehensive understanding of the impact of environmentally friendly science teaching aids in the form of a windmill in science education (Nisa & Sudarmin, 2016; Yuliani & Saragih, 2015).

Overall, the findings confirm that integrating environmentally friendly science teaching aids in the form of a windmill into experimental learning is an effective and impactful strategy for improving students' conceptual understanding of energy, particularly in elementary science education (Fitriana & Prayogi, 2023; Lestari & Widodo, 2022; Susi Subella, Lukman Hakim, 2023).

CONCLUSION

The integration of hands-on experimentation facilitated by eco-friendly pedagogical resources demonstrably enhances undergraduate students' conceptual grasp of electrical principles when contrasted with instruction devoid of such implements. This assertion is corroborated by the equipoise in initial assessment scores between the experimental and control cohorts, signifying comparable foundational competencies. Nevertheless, subsequent evaluations revealed a statistically significant disparity, $t(44) = 11.813$, $p < .001$, characterized by a mean divergence of 14.451 in favor of the experimental cohort. Furthermore, an N-gain statistical examination indicated that the experimental cohort achieved a moderate-to-high level of academic advancement (59.21%),

whereas the control group's progress was confined to a lower stratum (11.22%). The calculated effect size (Cohen's $d = 3.47$) signifies a profoundly substantial practical impact attributable to the intervention.

This investigation advances the discourse on constructivist learning paradigms through the presentation of empirical evidence. The findings indicate that the incorporation of eco-conscious scientific instructional materials within experiential learning modalities significantly augments advanced-order conceptual comprehension (C1–C4) in the milieu of Madrasah Ibtidaiyah settings. Specifically, this research substantiates that the synergistic combination of manipulative experimentation with sustainable, contextually relevant resources facilitates profound conceptual assimilation and fortifies learners' proficiencies in the application and critical analysis of scientific principles.

The current study's scope is circumscribed by a comparatively modest sample demographic, the utilization of a quasi-experimental framework eschewing random allocation, and an exclusive focus on transient learning achievements. Consequently, subsequent scholarly endeavors are advised to encompass more substantial and variegated participant groups, employ randomized experimental methodologies, and investigate enduring knowledge retention alongside expansive cognitive and affective ramifications. From a pedagogical standpoint, educators are exhorted to integrate environmentally sustainable friendly science teaching aids into science instruction to promote meaningful conceptual understanding and foster environmental awareness in elementary classrooms.

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