The Effect of the 5E Learning Model on High School Students' Cognitive Learning Outcomes and Renewable Energy Literacy

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Abstract *- The growing global energy crisis requires younger generations to possess adequate knowledge and awareness regarding the use of renewable energy. However, students' energy literacy remains relatively low, and instructional practices are often still conventional. This study aims to analyze the effect of the Learning Cycle 5E model on improving students' cognitive learning outcomes and energy literacy on the topic of renewable energy. A quantitative approach was employed using a quasi-experimental design with a nonequivalent control group design. The sample consisted of two Grade 10 classes from a senior high school in Samarinda, divided into an experimental group and a control group, each comprising 32 students. Data were collected through essay tests to assess cognitive learning outcomes and questionnaires to measure energy literacy. Data were analyzed using one-way ANOVA to determine the effect of the treatment. The results indicated a significant improvement in cognitive learning outcomes and students' attitudes toward energy literacy among those taught using the Learning Cycle 5E model. However, the basic knowledge and behavioral aspects did not show significant improvement, which may indicate that students had already possessed foundational environmental knowledge and pro-environmental habits influenced by the implementation of the Adiwiyata (eco-school) program. Future studies are encouraged to investigate deeper dimensions of energy literacy and to apply a longer intervention period to obtain a more comprehensive understanding of the learning model's effectiveness in schools implementing the Adiwiyata (eco-school) program.*

Keywords: *Cognitive Achievement; Energy Literacy; Learning Cycle 5E; Physics Education; Renewable Energy.*

INTRODUCTION

Energy is a fundamental necessity in modern life, influencing various aspects of a country's development (Yusup, 2017). The low utilization of renewable energy increases dependence on energy imports and heightens the risk of a national energy crisis (Bahij et al., 2020). This limited use is evident in Indonesia's heavy reliance on non-renewable energy sources such as coal, oil, and natural gas. However, the development and implementation of renewable energy have not met expectations or aligned with the National Strategic Plan (BPPT, 2014).

The younger generation plays a crucial role in sustaining energy availability by adopting energy-saving lifestyles from an early age (Bahij et al., 2019). Nevertheless, students' understanding of energy issues and conservation remains relatively low (Aziz et al., 2018). Limited energy literacy contributes to inefficient and irresponsible energy consumption behavior (Nugraha et al., 2022), despite the fact that energy literacy is essential for fostering awareness of sustainable energy use (Prati et al., 2017).

On the other hand, classroom practices still tend to rely on conventional, teacher-centered approaches, resulting in low levels of student engagement (Ariesandy, 2021). Such approaches often lead to boredom and negatively affect students' cognitive learning outcomes (Sanjaya et al., 2023). Teachers also tend to prioritize content mastery without providing sufficient opportunities for students to explore and construct concepts independently (Fuadi et al., 2020).

Ideally, learning should encourage active participation through critical thinking and problem-solving processes (Meutiawati, 2023). In practice, however, the 5E learning cycle is still rarely implemented in physics instruction, particularly in the topic of renewable energy (Armansyah, 2018). Monotonous and less contextual learning experiences make it difficult for students to understand energy concepts and their environmental implications (Aziz et al., 2018). The lack of variation in teaching methods also contributes to low cognitive learning outcomes and limited development of energy literacy in the learning process (Nugraha et al., 2022).

This study aims to provide a reference for an alternative instructional approach through the implementation of the 5E learning cycle model in renewable energy topics, in order to examine improvements in students' cognitive outcomes and energy literacy (Djadir et al., 2021). The model emphasizes active student engagement through five systematic phases: engagement, exploration, explanation, elaboration, and evaluation (Prayogi & Hidayat, 2013). Several studies have shown that this model is effective in enhancing conceptual understanding and learning motivation (Wulandari et al., 2024). However, its application in the context of energy literacy at the high school level remains limited (Santillán & Cedano, 2023). Therefore, this study seeks to contribute to the development of more relevant and contextual learning strategies for students.

RESEARCH METHODS

This study employed a quasi-experimental approach using a quantitative method with a nonequivalent control group design (Sugianto, 2023). Data were collected at a public senior high school in Samarinda during the second semester of the 2024/2025 academic year, involving two tenth-grade classes. The 5E learning cycle model was implemented in the experimental class, while a conventional learning model was applied in the control class (Prayogi & Hidayat, 2013). The classes were selected through purposive sampling, with each class consisting of 32 students.

Data were collected using two instruments: a cognitive learning outcomes test and an energy literacy questionnaire. The cognitive test consisted of 10 essay items designed to measure students' understanding of renewable energy concepts (Nurlindayani et al., 2020). Meanwhile, the questionnaire comprised 30 statements covering three aspects of energy literacy: basic knowledge, attitudes, and behaviors (DeWaters & Powers, 2011). Both instruments were administered before and after the instructional intervention in both groups.

Data analysis was conducted using descriptive and inferential statistical methods to compare improvements in cognitive learning outcomes and energy literacy (Arifin, 2012). The improvement in students' cognitive learning outcomes in the experimental class was analyzed using the normalized gain (N-Gain) test. The N-Gain score was calculated using the following formula:

$$< N - Gain >= \frac{<s_{posttest} - s_{pretest}>}{<s_{ideal} - s_{pretest}>} \quad (1)$$

This formula represents the normalized gain, calculated using IBM SPSS Statistics 26 software. The N-Gain values were classified into categories based on the criteria presented in Table 1.

Table 1. N-Gain Categories

N-Gain Value	Category
N-Gain > 0.70	High
0.30 ≤ *N-Gain* ≤ 0.70	Moderate
N-Gain < 0.30	Low

(Delfita, 2016)

Furthermore, to examine differences in students' energy literacy before and after the intervention, a One-Way ANOVA test was employed. One-Way ANOVA, also known as single-factor ANOVA, is a statistical method used to compare the means of more than two groups (Supriadi, 2021). The test was conducted using pretest and posttest scores from both groups. If the ANOVA results indicate a significance value (sig) of less than 0.05, it suggests a statistically significant difference between the control and experimental groups in the posttest. Conversely, if the significance value exceeds 0.05, the difference is considered not statistically significant.

RESULTS AND DISCUSSION

In the class that was not taught using the 5E learning cycle model, students administered both pretests and posttests in the form of written tests and questionnaires. However, the instruction was delivered using conventional teaching methods. In contrast, students in the experimental class were first given a pretest consisting of test items and a questionnaire before the learning activities began. Subsequently, the 5E learning cycle model was implemented during the instructional process. At the end of the lesson, students were asked to complete the posttest. The pretest and posttest data were then collected and analyzed by examining the total scores for each session of both the test and the questionnaire, enabling the identification of students' cognitive learning outcomes and energy literacy levels.

Results

The results of the data analysis from the pretest and posttest are presented in the following tables.

Table 2. N-Gain Results of the Experimental Class

Mean Pretest	Mean Posttest	N-Gain Score	Category
39,45	79,29	0,64	Moderate

Table 2 shows that the N-Gain score for students' cognitive learning outcomes is 0.64, which falls into the moderate category. The distribution of students' improvement in cognitive learning outcomes is presented in Table 3.

Table 3. Distribution of Students' N-Gain Categories

N-Gain Value	Category	Frequency
N-Gain > 0.70	High	12
0.30 ≤ *N-Gain* ≤ 0.70	Moderate	19
N-Gain < 0.30	Low	1

Based on the data in the table, the majority of students (19 students) experienced improvement in the moderate category. A total of 12 students achieved a high level of improvement, indicating that the implemented learning model was reasonably effective in enhancing students' understanding. Meanwhile, only one student fell into the low category, suggesting limited improvement in learning outcomes. Overall, these findings indicate that most students showed positive gains in learning outcomes, with only one student experiencing minimal improvement.

Table 4. Descriptive Statistics of Students' Cognitive Learning Outcomes

Statistic	Control		Experiment	
	Pretest	Posttest	Pretest	Posttest
Mean	40,46	62,73	39,45	79,29
Max	65	82,50	70	93
Min	10	42	20	60
Mean Difference	22,27		39,84	

Table 4 shows a difference in the mean cognitive learning outcomes of students based on the comparison of average scores in each class. The control class (without treatment) exhibited a mean difference of 22.27 between pretest and posttest scores. In contrast, the experimental class, which was taught using the 5E learning cycle model, showed a mean difference of 39.84. This indicates a substantially higher improvement in cognitive learning outcomes compared to the control class.

Table 5. Descriptive Statistics of the Basic Knowledge Aspect

Statistic	Control		Experiment	
	Pretest	Posttest	***Pretest***	Pretest
Mean	36,37	41,28	37,84	41,53
Max	45	46	46	49
Min	25	35	28	33
Mean Difference	4,91		3,69	

Table 5 indicates differences in the average scores of students' basic knowledge aspect across both classes. The control class showed a mean increase of 4.91, while the experimental class showed a slightly lower increase of 3.69. This suggests that the improvement in the basic knowledge aspect of energy literacy in the experimental class was lower than in the control class. However, in terms of overall mean scores, the experimental class still achieved a slightly higher average (by approximately 0.25) compared to the control class.

Table 6. Descriptive Statistics of the Attitude Aspect

Statistic	Control		Experiment	
	Pretest	Posttest	***Pretest***	Pretest
Mean	36,75	38,62	36,37	41,21
Max	41	32	45	49
Min	29	47	25	28
Mean Difference	1,87		4,84	

Table 6 presents the differences in mean scores for the attitude aspect. The control class, which received conventional instruction, showed a mean increase of 1.87. Meanwhile, the experimental class demonstrated a higher increase of 4.84. This indicates that the 5E learning cycle model was more effective in improving students' attitudes compared to traditional teaching methods.

Table 7. Descriptive Statistics of the Behavioral Aspect

Statistic	Control		Experiment	
	Pretest	Posttest	***Pretest***	Pretest
Mean	38,18	40,31	39,09	40,56
Max	45	50	45	49
Min	25	28	28	28
Mean Difference	2,13		1,47	

Table 7 shows the difference between pretest and posttest scores in the behavioral aspect. The control class exhibited a mean increase of 2.13, while the experimental class showed a smaller increase of 1.47. This suggests that the improvement in behavioral outcomes was slightly higher in the control class compared to the experimental class.

In addition, normality and homogeneity tests were conducted as part of the prerequisite analysis. The normality test was used to determine whether the data were normally distributed (Nuryadi et al., 2017), while the homogeneity test was employed to assess whether the data were homogeneous (Nuryadi et al., 2017). Similar to the main analysis, these tests were performed on both pretest and posttest data from the two groups. All statistical analyses were conducted using IBM SPSS Statistics 26 as the supporting software.

Table 8. Results of the Normality Test

Variable	Cognitive Outcomes		Basic Knowledge Aspect		Attitude Aspect		Behavioral Aspect	
	Sig.	**Descr**	**Sig.**	**Descr**	**Sig.**	**Descr**	**Sig.**	**Descr**
Control Pretest	0,101	Normal	0,320	Normal	0,090	Normal	0,073	Normal
Experimental Pretest	0,279	Normal	0,147	Normal	0,320	Normal	0,055	Normal
Control Posttest	0,518	Normal	0,215	Normal	0,247	Normal	0,783	Normal
Experimental Posttest	0,910	Normal	0,608	Normal	0,428	Normal	0,549	Normal

Table 8 shows that all pretest and posttest data in both the control and experimental groups have significant values greater than 0.05. Therefore, it can be concluded that the data are normally distributed and meet the assumptions required for parametric analysis.

Table 9. Results of the Homogeneity Test

Variable	Cognitive Outcomes		Basic Knowledge Aspect		Attitude Aspect		Behavioral Aspect	
	Sig.	**Descr**	**Sig.**	**Descr**	**Sig.**	**Sig.**	**Descr**	**Sig.**
Pretest	0,245	Homogeneous	0,279	Homogeneous	0,130	Homogeneous	0,123	Homogeneous
Posttest	0,801	Homogeneous	0,286	Homogeneous	0,137	Homogeneous	0,710	Homogeneous

Table 9 presents the results of the homogeneity test. The findings indicate that all significance values exceed 0.05 (sig > 0.05), suggesting that the data are homogeneous and that the assumption of homogeneity of variance is satisfied.

To examine differences in mean test scores between groups, a One-Way ANOVA was employed. One-Way ANOVA, also referred to as single-factor ANOVA, is a statistical method used to compare the means of more than two groups (Supriadi, 2021). In this study, the test was applied to both pretest and posttest scores of the control and experimental groups. The purpose of this analysis was to determine whether there were statistically significant differences between the two groups following the intervention. If the significance obtained from the ANOVA test is less than 0.05, it indicates a significant difference between the control and experimental groups. Conversely, if the significance value exceeds 0.05, no significant difference is observed. All statistical analyses were conducted using IBM SPSS Statistics 26 as the supporting software.

Table 10. Results of the One-Way ANOVA Test

Variable	Cognitive Outcomes	Basic Knowledge Aspect	Attitude Aspect	Behavioral Aspect
	Sig.	**Sig**	**Sig.**	**Sig.**
Pretest	0,760	0,112	0,667	0,391
Posttest	0,000	0,769	0,000	0,847

Table 10 presents the results of the one-way ANOVA test for both pretest and posttest across all measured aspects. For the pretest, all significance values (sig) are greater than 0.05, indicating that there were no statistically significant differences between the control and experimental groups prior to the instructional intervention. In other words, students' initial cognitive outcomes, basic knowledge, attitudes, and behavioral aspects of energy literacy were relatively equivalent across both groups.

For the posttest, the significance values for cognitive outcomes and the attitude aspect are 0.000 (sig < 0.05), indicating statistically significant differences between the experimental group (taught using the 5E learning cycle model) and the control group (taught using conventional methods). This finding suggests that the 5E model had a significant effect on improving students' cognitive learning outcomes and their attitudes toward energy literacy.

However, for the basic knowledge and behavioral aspects, the significance values are greater than 0.05 (sig > 0.05), indicating no statistically significant differences between the two groups. This implies that the implementation of the 5E learning model did not lead to a significantly greater improvement in students' basic knowledge or behavioral aspects of energy literacy compared to the conventional approach.

Discussion

The implementation of the 5E learning cycle model was conducted over five meetings specifically designed for the experimental class. In the first meeting, a pretest was administered to measure students' cognitive learning outcomes and their level of energy literacy. This assessment included essay questions to evaluate cognitive abilities, as well as instruments to assess students' basic knowledge, attitudes, and behaviors related to energy issues. During the second to fourth meetings, students were actively engaged in learning activities based on the 5E model, which were designed to provide contextual and interactive learning experiences. Group-based activities involved practical tasks focused on understanding and applying energy literacy concepts, where students were encouraged to propose ideas and solutions to energy-related problems. To facilitate these activities, student worksheets (*LKPD*) were provided, containing structured guidelines and tasks to be completed throughout the learning process.

Based on the N-Gain results presented in Table 2, the average pretest score of the experimental class was 39.45, which increased to 79.29 in the posttest. This improvement resulted in an N-Gain value of 0.64, categorized as moderate. This finding indicates that the implemented learning method effectively enhanced students' cognitive learning outcomes. Furthermore, Table 3 shows that most students were in the moderate category, followed by a number of students in the high category, with only one student in the low category. These findings suggest that the applied learning approach was sufficiently effective in improving students' understanding of the subject matter, as cognitive learning outcomes reflect internal changes in learners (Attamimi et al., 2023).

This result also aligns with constructivist theory, particularly as proposed by Piaget, which emphasizes that learners actively construct knowledge through interaction with their environment. Students are not merely passive recipients of information but actively process and interpret it (Blanzizki & Setiyawati, 2023).

The results of the One-Way ANOVA test indicate a significant difference between the experimental class taught using the 5E learning cycle model and the control class taught using conventional methods, with a significance value of 0.000 (sig < 0.05). This finding confirms that the 5E learning model significantly influences students' cognitive learning outcomes. This improvement is further supported by the higher mean gain in the experimental class (39.84) compared to the control class (22.27). Theoretically, the 5E model promotes active student engagement in concept acquisition through stages such as exploration and explanation. As noted by Djadir et al. (2021), this approach enhances reasoning skills and deep conceptual understanding. These findings are also supported by Muryadi et al. (2024), who emphasized that the 5E model enables students to construct knowledge actively through observation and direct experience, making it highly effective in improving cognitive achievement.

In addition, the ANOVA results indicate that students were able to effectively absorb the material delivered by the teacher. This is consistent with Nurlindayani et al. (2020), who define cognitive learning outcomes as students' ability to receive and internalize instructional content.

In contrast, the ANOVA results for the basic knowledge aspect yielded a significance value of 0.769 (sig > 0.05), indicating no significant difference between the experimental and control groups. One possible explanation is that students in both groups came from an *Adiwiyata* school environment, where energy and environmental issues had already been introduced through school programs such as greening initiatives, waste management, and energy-saving campaigns. As a result, students' baseline knowledge of energy was relatively similar both before and after the intervention.

For the attitude aspect, the ANOVA results showed a significance value of 0.000 (sig < 0.05), indicating a significant difference between the experimental and control groups. This suggests that the 5E learning cycle model positively influenced students' attitudes toward energy and environmental issues. This improvement can be attributed to the 5E approach, which encourages active exploration and reflection, thereby enhancing awareness and concern regarding responsible energy use. This finding is consistent with DeWaters and Powers (2011), who argue that energy literacy is shaped not only by knowledge but also by affective and value-based dimensions. Active and contextual learning approaches, such as the 5E model, allow students to experience the relevance of the material in real-life contexts, leading to stronger attitudinal changes.

For the behavioral aspect, the ANOVA results yielded a significance value of 0.847 (sig > 0.05), indicating no significant difference between the experimental and control groups. This limited impact on behavior may be explained by pre-existing habits and values established within the school environment. As an *Adiwiyata* school in Samarinda, students were already accustomed to energy-saving behaviors in daily activities, such as turning off lights when not in use and utilizing alternative energy sources. Moreover, behavioral change typically requires a longer period and continuous reinforcement from the social environment. Rohim et al. (2023) also noted that energy-saving behavior cannot be instantly altered through classroom instruction alone but requires long-term habituation and environmental support. Therefore, although the 5E model effectively enhances awareness, its impact on behavior requires more sustained and comprehensive strategies.

Overall, the implementation of the 5E learning cycle over five meetings demonstrate a strong alignment with constructivist principles and contributes to improvements in both cognitive learning outcomes and energy literacy. While no significant differences were observed between groups at the pretest stage, the post-intervention results revealed significant improvements, particularly in cognitive outcomes and attitudes within the experimental class. These findings reinforce the effectiveness of the 5E model in enhancing student engagement, independence, and positive attitudes toward energy issues (Wulandari et al., 2024; Muryadi et al., 2024).

However, the absence of significant differences in basic knowledge and behavioral aspects suggests that these dimensions are influenced by students' prior experiences and school culture. In *Adiwiyata* schools, where environmentally friendly practices such as the 6R principles and energy efficiency are already embedded, students' baseline knowledge and behaviors are relatively well established. As highlighted by DeWaters and Powers (2011), environmental context plays a critical role in shaping energy-related behaviors, which require long-term reinforcement rather than short-term instructional interventions. Therefore, while the 5E learning cycle is effective in improving cognitive and attitudinal outcomes, its impact on basic knowledge and behavior is contingent upon students' initial conditions and the surrounding school environment.

CONCLUSION

The findings indicate that students in the conventional class demonstrated relatively lower cognitive learning outcomes and did not show significant improvement in their understanding of energy across knowledge, attitude, and behavioral aspects. This suggests that conventional teaching methods are less effective in fostering comprehensive energy literacy.

In contrast, students who participated in the 5E learning cycle model exhibited notable improvements in cognitive learning outcomes and attitudes toward energy issues compared to those in the control class. The N-Gain analysis revealed that most students fell into the moderate to high categories, indicating that the model is effective in enhancing cognitive understanding. However, the impact of the 5E model on basic knowledge and behavioral aspects was not statistically significant. This may be attributed to students' prior exposure to energy-related knowledge and environmentally responsible behaviors in schools implementing the *Adiwiyata* program.

It is recommended that future studies focus on higher-order environmental literacy skills rather than basic knowledge and behavior, particularly in schools that have already implemented *Adiwiyata* programs. Researchers may also consider integrating more innovative or interdisciplinary learning models to further enhance students' critical thinking and real-world problem-solving skills. Additionally, longer intervention periods are suggested to provide a more comprehensive understanding of the long-term effects of the learning model.

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