

EFFECT OF PROBLEM-BASED LEARNING ASSISTED BY WORDWALL AND CHATGPT ON STUDENTS' COGNITIVE LEARNING OUTCOMES

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Abstract :

The purpose of this study was to investigate how the Problem-Based Learning (PBL), with the help of Wordwall and ChatGPT, affected the cognitive learning results of tenth-grade students at Public Senior High School 9 of Bengkulu City on the topic of global warming, as well as the magnitude of its effect. This study used a quasi-experimental approach with a nonequivalent control group design, with class X.5 serving as the experimental group and class X.2 serving as the control group. Purposive sampling was used to pick 30 students for each group. An essay test with eight approved items was used to gather data and proven to be reliable (Cronbach's $\alpha = 0,897$). The independent samples t-test findings demonstrated that the use of PBL assisted by Wordwall and ChatGPT had a significant effect on students' cognitive learning outcomes (Sig. < 0,001), with the increase in the The experimental group's average score (from 38,27 to 77,17) being higher than that in the control group (from 37,57 to 67,63), and the effect size (Cohen's $d = 1,00$) falling into the large category. The progressive integration is what makes this research novel of Wordwall at the problem orientation, analysis and evaluation stages, as well as ChatGPT at the investigation and product development stages within the PBL syntax. The study's findings suggest that incorporating Wordwall and ChatGPT into the PBL paradigm can be an alternate teaching method to enhance students' cognitive learning outcomes, especially when it comes to contextual physics subjects like global warming.

Keywords: ChatGPT; Problem-Based Learning; Wordwall

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INTRODUCTION

The transformation of education in the 21st century requires students not only to master knowledge but also to possess comprehensive cognitive skills, ranging from basic skills (remembering, comprehending, implementing) to higher-order abilities (creating, assessing, and analyzing), as well as the ability to use technology wisely (Faizah et al., 2024; Jayadi et al., 2020). In response to these demands, the Merdeka Curriculum promotes meaningful, contextual, and learner-centered learning (Cholilah et al., 2022). However, there are still issues with its implementation, as evidenced by the low levels of science literacy among Indonesian students. The results of the 2022 PISA recorded Indonesia's

science literacy score at 383 points, down from 396 points in 2018 and still only 34% of pupils achieved level 2, which is below the OECD average of 476 points (OECD, 2023). Suparya et al (2022) emphasize that low science literacy is closely linked to poor cognitive learning outcomes, as science literacy has been demonstrated to positively affect pupils' academic achievement. This situation is exacerbated by teaching practices that remain conventional and do little to encourage student engagement, making it necessary to adopt a learning model better suited to the demands of modern education (Yusmar & Fadilah, 2023).

The success of the learning process is demonstrated through improved learning outcomes, namely students' abilities as reflected in their report card grades as well as in improvements in knowledge, thinking skills, and scientific attitudes (Chaniago et al., 2022). Surya, Barlow, and Petty in Syah (2017), classify educational goals into three categories: the affective, cognitive, and psychomotor domains. Referring to the revision of Anderson and Krathwohl's Bloom's Taxonomy (2001), the dimensions of the cognitive process are divided into six levels that form the basis for measuring learning outcomes in the cognitive domain. These six levels are arranged hierarchically with different ability indicators. Recall (C1) is the ability to recognize and retrieve information that has been learned. Understanding (C2) encompasses the ability to interpret, classify, compare, draw conclusions, and explain a concept. Applying (C3) is the ability to use concepts, principles, or procedures to solve problems. Analyzing (C4) involves the ability to distinguish, organize, and connect information to identify relationships or causes of a phenomenon. Evaluating (C5) is the ability to assess, consider alternatives, and critique ideas or solutions based on specific criteria. Creating (C6) is the highest-level ability, involving the development, planning, and generation of new ideas, products, or solutions based on existing knowledge.

Problems in the cognitive domain are evident in studying physics. As a field of study that includes concepts, laws, facts, and principles and theories related to natural phenomena, physics is often considered difficult to understand, resulting in low student interest in learning. This situation is influenced by the complexity of the material as well as the suboptimal selection of learning media (Maulidina & Bhakti, 2020). One topic that demands conceptual understanding and problem-solving skills is global warming, as students are required to analyze the causes, impacts, and alternative solutions to environmental problems (Simatupang et al., 2025).

A well-designed and creative learning model can provide students with greater opportunities to better comprehend the material, retain concepts more effectively, and enhance their abilities in accordance with learning objectives (Syahidi et al., 2020). The PBL model is one pertinent substitute solution, which encourages active student engagement by using real-world issues as the core of learning. This model involves stages such as introducing students to the issue, setting them up for learning, directing both individual and group research, creating and presenting work products, and assessing and analyzing the problem-solving process (Cintami et al., 2024; Piyona et al., 2025). The effectiveness of PBL has been demonstrated by previous research; Suindhia (2023) reported an increase in physics learning achievement from 71.19% to 93.75% following the implementation of PBL, while Darta (2020) noted an increase in learning achievement from 35.90% to 82.05% among 11th-grade science students at Public Senior High School 1 Marga They received instruction utilizing a PBL approach. These findings confirm that PBL effectively improves learning outcomes because it emphasizes solving real-world problems.

In addition to the learning paradigm, media selection plays a critical role in enhancing the quality of learning. Wordwall is a web-based platform that offers a range of interactive educational activities, including tests, matching exercises, and educational games, thereby enhancing students' motivation, curiosity, and learning outcomes (Ernasari & Meilina, 2024; Yusni & Hurriyah, 2024). Ernasari and Meilina (2024) reported a A two-tailed significance score of 0.000 indicates a substantial difference between the learning outcomes of students using Wordwall and those in the control class. In line with this, Alfiaturrohman et al (2024) reported an increase in learning achievement from 11% during the pre-observation phase to 89% in cycle II following the implementation of PBL assisted by Wordwall. These results demonstrate that the integration of PBL with Wordwall may improve student learning outcomes by developing a more dynamic, effective, and engaging learning environment.

Technological advancements have also brought Artificial Intelligence (AI) as an innovation that can be utilized in learning. One rapidly developing form of AI is Artificial Narrow Intelligence (ANI)

in the form of chatbots that operate through machine learning and natural language processing to provide automatic responses (Grace et al., 2023). Chatbots can aid students in comprehending topics during the learning process, provide quick feedback, and facilitate personalized interactions (Bulabos & Millanar, 2024). One widely used chatbot is ChatGPT, which offers the advantages of easy access, quick responses, and the ability to explain concepts using clear, communicative language, thereby supporting self-directed learning (Suharmawan, 2023). Research by Fadillah et al (2024) shows that students perceive ChatGPT as helpful in improving conceptual understanding, while Sahabuddin et al. (2025) report that integrating ChatGPT into the PBL model enhances students' analytical thinking skills. Nevertheless, excessive use of AI has the potential to lead to cognitive dependence; therefore, its use still requires teacher guidance to ensure students continue to build knowledge independently (Setyawan et al., 2025).

Based on interviews with physics teachers at Public Senior High School 9 of Bengkulu City, although the merdeka curriculum with a deep learning approach has been implemented, Students in the tenth grade continue to have poor cognitive learning results. Evidence of this can be seen in the Mid-Semester Assessment (PTS) scores, where Classes X.2 and X.5, which served as the research samples, obtained average scores of 52,85 and 54,93, respectively. These results indicate that, overall, student learning outcomes in both classes remain below the school's established Minimum Competency Threshold of 76. Teachers have implemented the PBL model, but it is still interspersed with expository methods, so instruction is not yet fully student-centered. The use of technology has also not been optimized, with textbooks and printed worksheets serving as the primary learning resources and media. Teachers have adopted ChatGPT but have only used it to assist in developing instructional materials; it has not yet been directly incorporated into teaching and learning activities. Students have also become accustomed to using ChatGPT, but their use of it remains inappropriate because they tend to copy answers from ChatGPT without reprocessing the information obtained or conducting an analysis, which results in weak comprehension and a lack of independent learning.

Although the effectiveness of Problem-Based Learning (PBL), Wordwall, and ChatGPT has been widely reported in previous studies, the available evidence remains fragmented. Previous studies have investigated the implementation of PBL alone (Darta, 2020; Suindhia, 2023), the integration of PBL with Wordwall (Alfiaturrohman et al., 2024), the integration of PBL with ChatGPT (Sahabuddin et al., 2025), and the use of Wordwall (Ernasari & Meilina, 2024; Yusni & Hurriyah, 2024) or ChatGPT (Fadillah et al., 2024) as individual learning media. However, these studies have not examined the integrated use of PBL, Wordwall, and ChatGPT within a single learning framework, particularly through the stage-specific integration of Wordwall and ChatGPT according to their respective pedagogical functions. Consequently, empirical evidence remains limited regarding the effect of this structured integration on students' cognitive learning outcomes. This gap is theoretically important because Wordwall and ChatGPT serve complementary pedagogical functions within the PBL process. Wordwall supports student engagement, reinforces conceptual understanding, and facilitates formative assessment through interactive activities during the problem orientation, analysis, and evaluation stages, whereas ChatGPT provides personalized explanations, immediate feedback, and learning scaffolding during the investigation and product development stages.

Based on this research gap, this study aims to investigate how Problem-Based Learning (PBL) assisted by Wordwall and ChatGPT affects the cognitive learning outcomes of tenth-grade students at Public Senior High School 9 of Bengkulu City on the topic of global warming, as well as the magnitude of its effect. By integrating both technologies into the PBL process according to their respective pedagogical functions, this study is expected to provide empirical evidence regarding the effect of their stage-specific integration on students' cognitive learning outcomes while extending the theoretical understanding of stage-specific technology integration in Problem-Based Learning. Furthermore, the findings are expected to provide practical guidance for educators in integrating digital media and artificial intelligence (AI) into Problem-Based Learning to support 21st-century learning.

RESEARCH METHOD

Research Design

This study used a Nonequivalent Control Group Design in a quasi-experimental research design. The experimental group received an intervention, and a control group was included in the study for comparison; neither the experimental nor the control group was selected at random (Monalisa et al., 2025). Because the researchers were unable to allocate the research subjects at random, this approach was used. The research design used is shown in Table 1.

Table 1. Nonequivalent Control Group Design

Group	Pretest	Treatment	Posttest
Experimental	O ₁	X	O ₂
Control	O ₃	Y	O ₄

(Monalisa et al., 2025)

As shown in Table 1, both groups completed a pretest before the learning intervention and a posttest after the intervention to measure changes in students' cognitive learning outcomes. The difference between the two groups lay in the treatment provided. The experimental group learned using the Problem-Based Learning (PBL) model assisted by Wordwall and ChatGPT (X), while the control group learned using the regular PBL model at school (Y). Consequently, any differences in posttest performance between the two groups could be attributed to the integration of Wordwall and ChatGPT within the PBL model. This study was carried out at Public Senior High School 9 of Bengkulu City, located on WR. Supratman Street, Bentiring Sub-district, Muara Bangka Hulu District, Bengkulu City, Bengkulu Province, during the second semester of the 2025–2026 academic year.

Research Target/Subject

All 164 students in the 10th grade at Public Senior High School 9 of Bengkulu City during the 2025–2026 school year, spread throughout six classes (X.1 through X.6), made up the study's population. Purposive sampling, a method based on certain factors or standards pertinent to the study's goals, was used to choose the sample (Rahman & Alrashdan, 2026). The criteria used included: (1) being in the same grade level, (2) having relatively equivalent prior knowledge based on subject teachers' recommendations, (3) having the same number of students, (4) being instructed by the same physics instructor, and (5) possessing comparable facilities and learning environments. Class X.5 was chosen as the experimental class and class X.2 as the control class based on the outcomes of coordination and conversations with the physics professors. There are thirty pupils in each class.

Research Procedure

This study was conducted in three stages: preparation and planning, implementation, and data analysis, as illustrated in Figure 1.

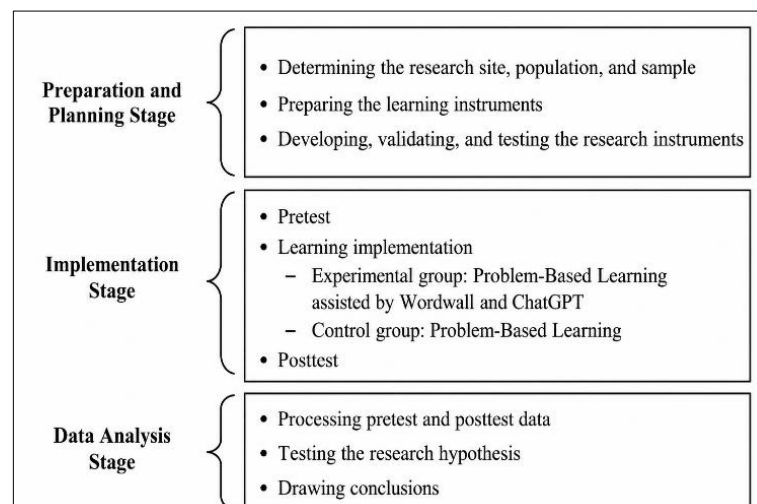


Figure 1. Research Procedure

As illustrated in Figure 1, the preparation and planning stage began with determining the research site, population, and sample, followed by preparing the learning materials and developing, validating, and testing the research instrument to ensure its suitability for measuring students' cognitive learning outcomes. In the implementation stage, a pretest was first administered to both the experimental and control groups to establish their baseline cognitive ability prior to the intervention. The learning intervention was then conducted over three meetings (6 JP; 1 JP = 40 minutes), during which the experimental group received Problem-Based Learning (PBL) assisted by Wordwall and ChatGPT, while the control group engaged in instruction using the typical PBL model used at the school. Upon completion of the intervention, a posttest identical in form to the pretest was administered to both groups to measure changes in students' cognitive learning outcomes. Finally, during the data analysis stage, the pretest and posttest scores were analyzed, the research hypothesis was tested, and conclusions were drawn regarding the effect of the instructional intervention.

Instruments, and Data Collection Techniques

This study's data gathering was carried out utilizing four techniques: observation to obtain an overview of classroom facilities and characteristics; interviews to gather information about the instructional models implemented by teachers and the challenges they faced; documentation in the form of field notes and photos of events; and assessments using pretest and posttest results to gauge students' cognitive learning outcomes.

The test instrument consisted of eight essay questions designed to measure students' cognitive learning outcomes on the topic of Global Warming. The questions were created using Bloom's Revised Taxonomy's cognitive process dimensions of Levels C2 (understanding), C3 (applying), C4 (analyzing), and C5 (evaluating) (Anderson & Krathwohl, 2001). Each item was constructed based on a test blueprint that aligned the learning indicators with the corresponding cognitive levels to ensure that the instrument measured students' cognitive abilities progressively. The blueprint of the cognitive learning outcomes test instrument is presented in Table 2.

Table 2. Blueprint of the Cognitive Learning Outcomes Test Instrument

Learning Indicator	Cognitive Level (Revised Bloom's Taxonomy)	Item Number
Understand the phenomena of global warming and climate change.	C2 (understanding)	1
Understand the basic concept of the greenhouse effect.	C2 (understanding)	2
Apply the concept of heat radiation to explain the greenhouse effect in everyday life.	C3 (applying)	3
Apply the concept of the greenhouse effect to explain the increase in the Earth's temperature.	C3 (applying)	4
Analyze the relationship between human activities and global warming.	C4 (analyzing)	5
Analyze the impacts of climate change on food security.	C4 (analyzing)	6
Evaluate efforts to mitigate global warming.	C5 (evaluating)	7
Evaluate solutions to the impacts of sea level rise.	C5 (evaluating)	8

As shown in Table 2, the instrument covers four cognitive levels of Bloom's Revised Taxonomy, ranging from understanding (C2) to evaluating (C5). The way the items are distributed among various cognitive levels guarantees that the test gradually evaluates students' cognitive learning results, from conceptual comprehension to higher-order thinking abilities needed for assessing and analyzing global warming-related problems. Before use, the test instrument was evaluated by three experts, including One physics instructor and two university professors, to assess its content validity using an expert

judgment sheet. The evaluated questions were then revised with the assistance of the supervising professor if any items were deemed inappropriate, before being empirically 30 non-sample students who have studied the global warming content participated in the pilot exam. The validity and reliability of the instrument, as well as the degree of difficulty of the test items, were ascertained using the pilot test results.

Data Analysis Technique

IBM SPSS Statistics version 29.0 was used to analyze the data based on the experimental and control classes' pretest and posttest results. The mean, maximum value, minimum value, and standard deviation were utilized in descriptive analysis to characterize the data (Darmawan, 2023). Inferential analysis started with a homogeneity test using Levene's test and a normality test using the Shapiro-Wilk test, which was used because each group's sample size was fewer than 50 pupils. If the significance value (Sig.) was more than 0,05, the data were deemed homogenous and normally distributed (Nurhasanah, 2023; Usmani, 2020). The hypothesis was examined using the Independent Samples t-Test at a significance level of $\alpha = 0,05$ after passing the necessary tests (Sugiyono, 2020).

The hypotheses tested were H_0 : there is no difference in cognitive learning objectives amongst pupils utilizing the PBL paradigm with the support of Wordwall and ChatGPT and students learning using the PBL model without Wordwall and ChatGPT's help; and H_a : the two groups' cognitive learning results differ. Testing decisions were based on the significance value; that is, H_0 was rejected if the Sig. value was $< 0,05$. If the The results of the test showed a substantial effect, and the effect's size of the intervention could be calculated using Cohen's d; the interpretation of the values for effect size is presented in Table 3 (Cohen, 1988).

Table 3. Criteria for Interpreting Effect Sizes

Effect Size (d)	Interpretation
$0,2 \leq d < 0,5$	Small
$0,5 \leq d < 0,8$	Medium
$d \geq 0,8$	Large

(Cohen, 1988)

As depicted in Table 3, these criteria were used as the basis for interpreting the magnitude of the intervention effect observed in this study. These criteria were used to classify the Cohen's d value calculated to ascertain whether the cognitive learning outcomes of students were small, medium, or large as a result of the implementation of PBL assisted by Wordwall and ChatGPT.

RESULTS AND DISCUSSION

Item validity indicates each item's ability to measure the aspect it is intended to measure, as well as its alignment with the total score. In this investigation, Pearson's product-moment correlation was used to assess the instrument's validity, calculated using SPSS version 29.0. The equation for Pearson's product-moment correlation is shown in Equation (1).

$$r_{xy} = \frac{n \sum xy - (\sum x)(\sum y)}{\sqrt{\{n \sum x^2 - (\sum x)^2\} \{n \sum y^2 - (\sum y)^2\}}} \quad (1)$$

(Fatayah et al., 2022)

Description :

r_{xy} = correlation coefficient
 x = score of each test item
 y = total score
 n = number of respondents

If a test item's significance value (Sig.) is less than 0,05, it is deemed legitimate and a correlation value (calculated r) higher than the table r value at the 0,05 significance level (Fatayah et al., 2022).

Validity testing was conducted on the eight test items used as the research instrument. Table 4 displays the validity test results.

Table 4. Results of the Test Instrument Validity Test

Item	r Calculated	r Table (N=30, $\alpha=0,05$)	Sig. (2-tailed)	Description
Item 1	0,596	0,361	< 0,001	Valid
Item 2	0,850	0,361	< 0,001	Valid
Item 3	0,828	0,361	< 0,001	Valid
Item 4	0,769	0,361	< 0,001	Valid
Item 5	0,704	0,361	< 0,001	Valid
Item 6	0,866	0,361	< 0,001	Valid
Item 7	0,902	0,361	< 0,001	Valid
Item 8	0,905	0,361	< 0,001	Valid

Based on Table 4, all test items whose computed r value is higher than the table r value and a significance level (Sig., 2-tailed) < 0.05; therefore, all eight test items are deemed valid. These results indicate that each test item is capable of measuring cognitive learning outcomes in accordance with the established indicators. Thus, all test items meet the validity criteria and are suitable for use as a research instrument to assess pupils' cognitive learning results about global warming.

The reliability of Cronbach's alpha, a measure of internal consistency that shows how consistently the instrument's items measure the same construct, was used to examine the instrument. Better internal consistency is indicated by Cronbach's alpha values, which range from 0 to 1. If the instrument's Cronbach's alpha value is more than 0,70, it is deemed dependable (Surucu & Maslakci, 2020). Table 5 displays the reliability test results.

Table 5. Results of the Test Instrument Reliability Test

Cronbach's Alpha	Description
0,897	Reliabel

Based on Table 5, The result was a Cronbach's alpha value of 0,897. This number is higher than the 0,70 minimal criterion, so the instrument is deemed reliable (Surucu & Maslakci, 2020). These findings show that the device has outstanding internal consistency, enabling it to provide relatively consistent measurement results when used under similar conditions. Next, Each test item's degree of difficulty was analyzed using the difficulty index, which is a measure used to determine how easy or difficult a test item is based on the proportion of students who answered it correctly (Ati et al., 2026) . Tthe results presented in Table 6.

Table 6. Results of the Test Item Difficulty Analysis

Item	Max Skor	Mean Skor	difficulty index	Interpretation
Item 1	7	5,03	0,71	Easy
Item 2	7	4,07	0,58	Medium
Item 3	11	7,60	0,69	Medium
Item 4	11	5,50	0,50	Medium
Item 5	14	5,47	0,39	Medium
Item 6	14	4,57	0,33	Medium
Item 7	18	3,77	0,20	Difficult
Item 8	18	5,43	0,30	Difficult

Table 6 shows that of the eight test items, one item is classified as easy, five are classified as medium, and two as difficult, based on Arikunto (2018) criteria for interpreting difficulty levels: a difficulty index of 0,00–0,30 (difficult), 0,31–0,70 (medium), and 0,71–1,00 (easy). This distribution of difficulty levels indicates that the instrument contains a proportional variety of difficulty levels to measure students' cognitive abilities at various levels. Overall, the instrument validation results show

that all test items meet the requirements for a research instrument, as assessed Regarding validity, reliability, and degree of difficulty.

The instrument, having met these criteria, was subsequently used to collect information on the cognitive learning results of the students in both classes through the use of pretests and posttests. The pretest and posttest results of the experimental class, which was taught using the PBL model with assistance from Wordwall and ChatGPT, and the control class, which was taught using the school's standard PBL model, provided information on students' cognitive learning outcomes regarding the topic of global warming. Table 7 displays descriptive data for both groups' scores.

Table 7. Descriptive statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Control Pretest	30	20	57	37,57	10,843
Control Posttest	30	55	88	67,63	9,227
Experimental Pretest	30	20	56	38,27	10,346
Experimental Posttest	30	60	93	77,17	9,710
Valid N (listwise)	30				

Table 7 shows that before The experimental, control, and treatment groups had comparatively equivalent initial abilities. This is indicated by the mean pretest scores of 37,57 (SD = 10,843) for the control group and 38,27 (SD = 10,346) for the experimental group. After the treatment, the mean posttest scores increased in both groups. However, the improvement was greater in the experimental group, with an increase of 38.90 points (from 38,27 to 77,17), compared with an increase of 30,06 points (from 37,57 to 67,63) in the control group. In addition, the decrease in the standard deviation in both groups indicates that students' scores became more homogeneous after the learning process.

Based on According to the descriptive statistical analysis, both groups' mean pretest scores showed comparatively similar starting abilities. However, an Independent Samples t-Test was performed on the pretest data to verify that there was no significant difference in baseline ability between the experimental and control classes. Table 8 displays the test's findings.

Table 8. Findings from the Pretest's Independent Samples t-Test

Data	t	df	Sig. (2-tailed)
Pretest	-0,256	58	0,799

Table 8 shows showed the significance value (Sig., 2-tailed) was 0,799 ($> 0,05$), indicating that H_0 was accepted and that the experimental and control groups' cognitive learning results did not vary significantly classes before the treatment was administered. Thus, both groups can be said to have equivalent initial abilities prior to the learning model's implementation, so that differences in cognitive learning outcomes that emerge after the treatment can be more reliably attributed on the course of treatment rather than variations in starting skills between the groups.

The inferential analysis began with a Shapiro-Wilk test for normality since each group's sample size was smaller than fifty pupils. A homogeneity test using Levene's test came next. The information was regarded as homogenous and regularly distributed if the significance value (Sig.) was $> 0,05$ (Nurhasanah, 2023; Usmadi, 2020). Table 9 displays the normalcy test results.

Table 9. Shapiro-Wilk Normality Test

Group		Shapiro-Wilk		
		Statistic	df	Sig.
Results	Control Pretest	0,956	30	0,244
	Control Posttest	0,939	30	0,086
	Experimental Pretest	0,959	30	0,294
	Experimental Posttest	0,953	30	0,200

Table 9 shows that all pretest and posttest data for both groups had significance values larger than 0,05, all of the data were considered to be regularly distributed. Testing for homogeneity of variances between the experimental and control classes came next once it was shown that the data were normally distributed. To make sure that the data from both groups satisfied the condition of homogeneity of variances—that is, when the significance value (Sig.) is $> 0,05$ —the homogeneity test was performed using Levene's test on the pretest and posttest data (Usmadi, 2020). Table 10 displays the findings of Levene's test for homogeneity of variances.

Table 10. Findings from the Pretest and Posttest Homogeneity Test

Data	Lavene Statistic (Based on mean)	df1	df2	Sig
Pretest	0,383	1	58	0,538
Posttest	0,105	1	58	0,747

Table 10 shows that both the pretest (0,538) and posttest (0,747) significance values are higher than 0,05. These findings show that the data variances in the experimental and control groups are similar. The Independent Samples t-test may be used to evaluate hypotheses if the criteria of homogeneity and normality are satisfied. The test conclusion is based on the significance value, with H_0 being rejected if $\text{Sig.} < 0,05$ (Sugiyono, 2020). Table 11 displays the independent samples t-test findings.

Table 11. Findings from the Posttest's Independent-Samples t-Test

Data	t	df	Sig. (2-tailed)
Posttest	-3,898	58	$< 0,001$

Table 11 shows that the posttest data yielded a p-value = $< 0,001$ ($< 0,05$), indicating that H_0 was rejected and that the experimental and control groups' cognitive learning results differed significantly following the intervention. Cohen's d effect size was then used to determine the extent of the impact of applying the Problem-Based Learning model with Wordwall and ChatGPT. The findings are shown in Table 12.

Table 12. Effect Size Analysis Results

Group	Mean	Standard Deviation	Effect Size (Cohen's d)
Control	67,63	9,227	1,00
Experimental	77,17	9,710	

Table 12 shows an effect size (Cohen's d) of 1.00, which falls into the "large" category (Cohen, 1988). This indicates that the PBL model's application, assisted by Wordwall and ChatGPT, improved pupils' performance in a way that was both practically and statistically significant cognitive learning outcomes on the topic of global warming.

The equivalence of the initial skills of the two groups, confirmed by the non-significant results of the pretest hypothesis test (Sig. = 0,799), provides a strong basis for believing that the differences in posttest results that emerged later were truly attributable on the course of treatment rather than variations in the pupils' beginning characteristics. This aligns with the principles of quasi-experimental design, which state that the two classes selected as samples must be comparable. In other words, students in both classes should have relatively similar initial characteristics so that one class can serve as a comparison group (Isnawan, 2020).

The greater score increase in the experimental class, supported by hypothesis testing results demonstrating a considerable effect size and a significant difference between the two groups (Sig. < 0,001) ($d = 1,00$), indicates that the implementation of PBL assisted by Wordwall and ChatGPT has a major effect in raising pupils' cognitive learning outcomes. The control class, which also applied the PBL model but without the assistance of Wordwall and ChatGPT, despite using the same learning syntax, had students with more limited opportunities to explore concepts independently and reinforce understanding thru interactive media. The idea that learning media is one of the key elements impacting the effectiveness of the learning process supports this conclusion. Students' motivation, focus, and engagement may all be increased via engaging and interactive media, which facilitates their understanding of the material being taught (Fauziah & Sulisworo, 2022).

The role of Wordwall in the problem orientation, analysis and evaluation stages appears consistent with previous studies that show interactive quizzes based on gamification can enhance student motivation and learning outcomes, both in physics (Alfiaturrohman et al., 2024; Ermasari & Meilina, 2024) and in other subjects such as mathematics when combined with PBL (Ariyanto et al., 2023; Fistanti et al., 2024). Within the framework of this study, the Wordwall quiz at the beginning of the session serves to activate students' prior knowledge about the symptoms of global warming that they often hear but have not yet understood scientifically, while the Wordwall quiz at the end of the session serves to reinforce the concepts that have been learned, so that understanding does not stop at the stage of recognition but is repeated and strengthened in an enjoyable atmosphere. The implementation of Wordwall in each session of this study is presented in Figure 2.

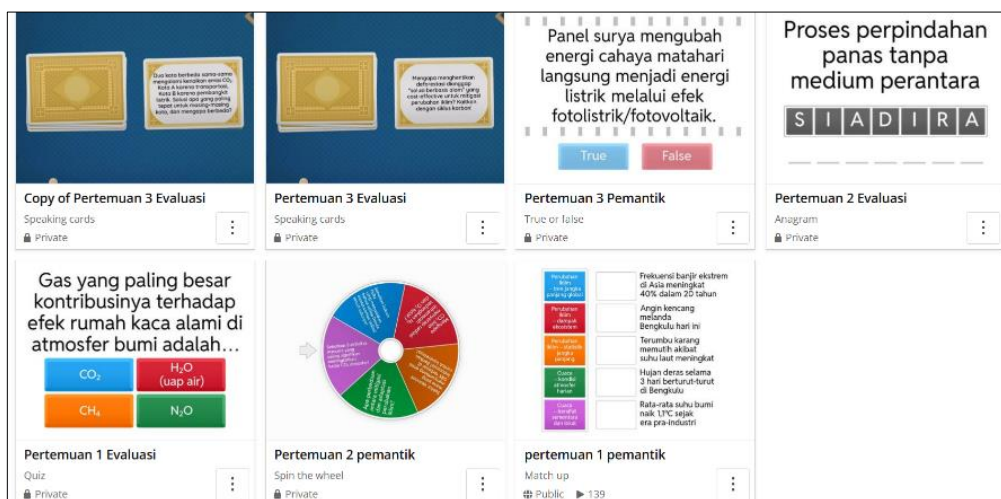


Figure 2. Wordwall Quiz in the Problem Based Learning syntax

The implementation of Wordwall in this research was carried out variably according to the learning objectives in each session. At the problem orientation stage, Wordwall is used as an engaging activity thru games like match up, spin the wheel, and true or false to activate prior knowledge and draw students' attention to the issue of global warming. Meanwhile, at the analysis and evaluation stage, Wordwall is utilized thru interactive quizzes such as quizzes, anagrams, and speaking cards to measure and reinforce the comprehension of the acquired notions. The variety of activities creates a more interactive, enjoyable learning atmosphere and promotes students' active involvement in the learning process.

The implementation of ChatGPT in this research is carried out as a support for the PBL process, especially in the investigation and concept understanding development stages. Students utilize ChatGPT to obtain information about global warming, such as the definition of global warming, its difference from climate change, scientific evidence, and its impact on daily life, using language appropriate to the understanding level of high school students. Additionally, students can ask follow-up questions according to their learning needs, making the information search process more flexible and encouraging student-centered learning. During this process, the teacher continues to act as a facilitator, assisting

pupils in using appropriate prompts, directing discussions, and ensuring that the information obtained from ChatGPT aligns with the scientific concepts being studied.

That role aligns with the characteristics of ChatGPT as an Artificial Intelligence (AI) technology capable of providing quick responses, presenting explanations in easily understandable language, and promoting self-directed learning in line with students' requirements (Suharmawan, 2023). Bulabos also supports the study's findings and Millanar (2024), who concluded that the use of chatbots can improve students' physics learning outcomes thru interactive learning, as well as the research by Sahabuddin et al (2025), which showed that the use of ChatGPT in the PBL model is more effective in enhancing analytical thinking skills. Additionally, based on conversations and observations with physics teachers and students at Public Senior High School 9 of Bengkulu City, ChatGPT is an Artificial Intelligence (AI) technology that is more well-known and has been used by all students compared to similar AIs, so its use in learning does not require significant adaptation. An example of the ChatGPT prompt used is shown in picture 3.



Figure 3. Example of student interaction with ChatGPT in learning

The roles of Wordwall and ChatGPT at each stage of the PBL syntax are ultimately directed to encourage pupils to meet their cognitive learning objectives at various levels of thinking, as reflected in the composition of this research instrument. In this context, the PBL syntax that requires students to analyze problems and formulate solutions provides direct practice space from level C2 to C5. Wordwall, at the orientation, analysis and evaluation stages, plays a greater role in reinforcing level C2 thru the repetition of basic concepts, while ChatGPT, at the investigation stage, helps students bridge levels C3 to C5 by providing additional explanations when they struggle to apply, analyze, or evaluate global warming issues independently. Meanwhile, the control class that applied the same PBL syntax without the assistance of these two media had more limited opportunities to utilize interactive learning resources and direct feedback during the learning process, which may explain why the experimental class's thinking level developed further compared to the control class.

The findings of this study indicate that the integration of Wordwall and ChatGPT at different stages of the Problem-Based Learning (PBL) syntax allows each medium to perform complementary pedagogical functions. Wordwall supports the activation of prior knowledge, concept reinforcement, and formative assessment at the problem orientation, analysis and evaluation stages, while ChatGPT facilitates investigation and development of work through personalised explanations, direct feedback, and scaffolding. These findings indicate that the impact of implementing PBL assisted by Wordwall and ChatGPT on cognitive learning outcomes is not only related to the use of digital media but also to the placement of each media according to its pedagogical function at the stages of PBL syntax. Thus, this research expands the understanding of technology integration in PBL through a stage-specific integration approach.

The novelty of this research lies in the structured integration of Wordwall and ChatGPT within a single PBL syntax. The results of this study provide empirical evidence that the application of Wordwall at the problem orientation, analysis, and evaluation stages, and ChatGPT at the investigation

and product development stages, influences students' cognitive learning outcomes. Practically, these findings indicate that teachers can integrate both media according to their pedagogical functions to support problem-based learning. However, the use of ChatGPT still requires teacher guidance so that students can critically utilize the information obtained and not rely on AI responses.

However, this study has several limitations. It involved only one school with two sample classes, limiting the generalizability of the findings. In addition, each learning session lasted only 2 lesson hours (2×40 minutes), making it challenging to allocate sufficient time for every stage of the PBL process while optimally integrating both Wordwall and ChatGPT, which may have limited the development of students' higher-order thinking skills. Therefore, future research is recommended to involve a larger and more diverse sample, provide more adequate instructional time, carefully plan the time allocation for each stage of the PBL process, and develop more specific instruments for assessing higher-order thinking skills.

CONCLUSION

Based on the findings and discussion, it can be concluded that the implementation of Problem-Based Learning (PBL) assisted by Wordwall and ChatGPT had a significant and large effect on the cognitive learning outcomes of tenth-grade students at Public Senior High School 9 of Bengkulu City on the topic of global warming, as demonstrated by the Independent Samples t-Test results (Sig. $< 0,001$) and a large effect size (Cohen's $d = 1,00$). This study contributes empirical evidence that the stage-specific integration of Wordwall for problem orientation, analysis and evaluation, and ChatGPT for investigation and product development, according to their complementary pedagogical functions, has an effect on students' cognitive learning outcomes within the PBL process. Future research is recommended to involve a larger and more diverse sample, allocate sufficient time for each stage of the PBL process, and employ more specific instruments for assessing higher-order thinking skills.

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