



# The Influence of Wordwall-Assisted Problem-Based Learning (PBL) on Electrical Energy Concept Mastery Reviewed from the Prior Knowledge of Fifth-Grade Elementary Students

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**Abstract:** While Problem-Based Learning (PBL) and Wordwall have been studied individually, empirical research integrating both to address abstract science topics in elementary schools remains limited, leaving a gap in understanding how this combination interacts with students' prior knowledge. This study analyzes the influence of the Wordwall-assisted PBL model on fifth-grade students' mastery of electrical energy concepts, considering their prior knowledge. A quantitative quasi-experimental design with a posttest-only control group was used, involving a total sample of 33 students (17 in the experimental class and 16 in the control class). Instruments included validated and reliable prior knowledge and concept mastery tests. Two-Way ANOVA results show significant main effects on concept mastery based on the learning model and prior knowledge levels ( $p < 0.05$ ). The experimental group achieved a notably higher mean score (88.75) compared to the control group (66.50), with the learning model exerting a strong effect size (Partial Eta Squared,  $\eta_p^2 = 0.872$ ) on concept mastery. Crucially, no significant interaction effect was found between the learning model and prior knowledge ( $p = 0.861$ ), indicating that the Wordwall-assisted PBL model consistently and uniformly enhances learning outcomes for students across all initial ability levels.

**Keywords:** Concept mastery; Electrical energy; Prior knowledge; Problem-based learning (PBL); Wordwall

## Introduction

The escalation of science and technology demands a transformation in elementary education to cultivate scientific thinking and sustainable behavior. Natural Science (IPA) education plays a strategic role in constructing contextual and applicative competencies (Chen et al., 2017; Vieira & Tenreiro-Vieira, 2016). A substantial understanding of scientific concepts at an early age serves as the foundation for logical reasoning and scientific literacy relevant to daily life (Dawson et al., 2024). Therefore, elementary science learning must shift from rote factual mastery toward the formation of a meaningful concept mastery structure.

Electrical energy material in fifth grade is a vital pillar in building this conceptual foundation. Given its

urgency in daily activities, energy literacy for elementary students has become increasingly crucial (Martins et al., 2020; Poimenidis et al., 2022). Energy learning achieves optimal effectiveness when students are actively involved through deep, contextual learning experiences that correlate the material with real-world phenomena (Gill & Lang, 2018; Pietrapertosa et al., 2021). However, field reality indicates a low level of concept mastery, largely caused by the dominance of teacher-centered direct learning. This passive ecosystem demands pedagogical innovations capable of activating student engagement, especially regarding abstract topics like electrical energy.

The Problem-Based Learning (PBL) model offers a relevant solution to address this challenge. PBL prioritizes authentic problems that trigger critical

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thinking, active investigation, and concept mastery (Muliyadi et al., 2026; Tisna et al., 2024). Literature confirms that PBL significantly enhances high-level thinking skills, mitigates low motivation, and provides more impressive outcomes compared to conventional methods (Astra et al., 2024; Fitria & Annisa, 2024; Shishigu et al., 2018). To optimize PBL for elementary students who require interactive stimulation, Wordwall emerges as an adaptive web-based digital platform (Nenohai et al., 2022). Integrating Wordwall facilitates a game-based learning approach that increases student focus and participation (Hamidah et al., 2023), which correlates positively with enhanced science learning outcomes (Damayanti et al., 2026; Marlina et al., 2025; Sukma & Handayani, 2022)

Beyond external interventions, prior knowledge is a critical internal determinant of learning success, representing a student's cognitive readiness to assimilate new information. While students with high prior knowledge are generally adaptive to problem-based learning, those with low prior knowledge require additional scaffolding (Jatisunda & Nahdi, 2020). Prior knowledge strongly dictates the effectiveness of both the learning process and digital-based outcomes (Shi et al., 2020). Although the effectiveness of PBL and Wordwall has been widely studied partially, empirical research integrating both variables while considering prior knowledge in elementary electrical energy topics remains limited.

The distinct novelty of this research lies in its integrative approach, establishing an ecosystem where external pedagogical intervention, the technological synchronization of digital gamification through Wordwall inside the syntax of authentic PBL is systematically examined against students' internal cognitive baselines (prior knowledge). This specific interaction remains an unexplored domain in elementary science education. This study is highly important to conduct for several logical reasons. First, electrical energy is inherently abstract yet universally practical in the 21st century; failing to master this concept prevents young learners from developing functional energy literacy and eco-sustainable behaviors. Second, elementary students are in a cognitive transition stage where they require immediate, concrete, and gamified feedback to map abstract scientific concepts into their long-term memory. Third, by evaluating the moderator variable of prior knowledge, this research prevents the common "one-size-fits-all" pedagogical trap, offering a clear empirical prescription on how digital problem-solving models can be tailored to support both high-achieving and low-achieving students equitably. Ultimately, this study directly bridges the gap between digital technological

integration and foundational cognitive architecture in elementary classrooms.

To fill this gap, this study seeks to fill that gap by analyzing the influence of the Wordwall-assisted PBL model on the mastery of electrical energy concepts, reviewed from the prior knowledge of fifth-grade elementary school students. These findings are expected to provide an empirical contribution to the development of science learning innovations that are adaptive to the characteristics of elementary school students.

## Method

This study employs a quantitative approach with a quasi-experimental research design, specifically utilizing the Posttest-Only Control Group Design. This design was selected to evaluate the simultaneous effects of the independent and moderator variables on the dependent variable (Creswell, 2002). The independent variable is the learning model (Wordwall-assisted PBL vs. Conventional), the moderator variable is students' prior knowledge (High vs. Low), and the dependent variable is the mastery of electrical energy concepts.

The research population includes all fifth-grade students at public elementary schools in Saradan District, Madiun Regency, for the 2025/2026 academic year. A purposive sampling technique was implemented, selecting two classes with equivalent academic baselines and characteristics: the fifth-grade class of SDN Sumbergandu 02 (n=17) as the experimental group utilizing the Wordwall-assisted PBL model, and the fifth-grade class of SDN Sumbergandu 01 (n=16) as the control group utilizing conventional learning methods. To minimize teacher bias as an external variable, both classes were taught by the same science teacher who had been trained in the protocol. Environmental variables were also controlled by aligning the learning schedules, duration per session (2 x times 35 minutes), and instructional materials across both groups. as the control group utilizing conventional learning methods. The research was conducted through three primary stages, as presented in Figure 1 below.



Figure 1. Research procedure

The research was conducted through three primary phases (Bloom, 2012). The pre-experimental stage involved observation and the administration of a prior knowledge test (Feely et al., 2018). Students were categorized into High and Low prior knowledge groups based on the median score split. The median was deliberately chosen as the statistical cut-off to ensure an objective, balanced, and equal distribution of sample sizes within each cell, minimizing skewness in the subsequent factorial analysis. The experimental stage consisted of treatments spanning four intensive meetings (Kim & Steiner, 2016). While a four-meeting duration is relatively concise due to curriculum timeline constraints, its robustness was preserved by utilizing highly focused, continuous PBL syntax integrated with Wordwall’s interactive features in every session to ensure maximum concept immersion. The study concluded with the post-experimental stage, where an electrical energy concept mastery post-test was administered to both groups.

Concept mastery data were collected using an objective instrument consisting of 20 multiple-choice questions. The instrument underwent rigorous content validity testing by experts as well as empirical validity testing. The empirical test confirmed that all items were

valid, and the reliability test using Cronbach's Alpha yielded a coefficient of 0.83, indicating high internal consistency and feasibility for data collection.

Data analysis techniques included prerequisite testing and hypothesis testing. Normality was evaluated using the Kolmogorov-Smirnov method, and homogeneity of variance was assessed via Levene’s Test (Lago & Carlos, 2026). Once the parametric prerequisites were satisfied, hypothesis testing was performed using Two-Way Analysis of Variance (ANOVA) at a significance level of  $\alpha = 0.05$  via SPSS version 26.0 software. This analysis was utilized to examine the main effects of the learning model, the main effects of prior knowledge, and the interaction effects between both variables on the mastery of electrical energy concepts.

**Result and Discussion**

*Result*

The normality testing in this study was conducted using the Kolmogorov–Smirnov and Shapiro–Wilk tests via SPSS software version 26.0 at a significance level of 0.05. The results of the normality tests are presented in Table 1 below.

**Table 1.** The Results of the Normality Tests

Score	Group	Kolmogorov-Smirnov <sup>a</sup>			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
	Control_low_prior_knowledge	0.174	10	0.200*	0.952	10	0.691
	Control_high_prior_knowledge	0.183	6	0.200*	0.960	6	0.820
	Exp_low_prior_knowledge	0.178	10	0.200*	0.907	10	0.258
	Exp_high_prior_knowledge	0.214	7	0.200*	0.858	7	0.144

Normality tests using both the Kolmogorov–Smirnov and Shapiro–Wilk methods prove that the significance values for all four groups are greater than 0.05 ( $p > 0.05$ ). This indicates that the electrical energy concept mastery test data across all groups are normally distributed; therefore, the analysis can proceed to the next prerequisite test, namely the homogeneity test.

The homogeneity test is conducted to determine whether the data variance among the research groups is equal or homogeneous. In this study, homogeneity was tested using Levene’s Test at a significance level of 0.05. The results of the homogeneity of variance test are presented in Table 2 below.

**Table 2.** Results of the Homogeneity of Variance Test

	Levene Statistic	df1	df2	Sig.
Based on Mean	0.584	3	29	0.630
Based on Median	0.525	3	29	0.669
Based on Median and with adjusted df	0.525	3	25.781	0.669
Based on Trimmed Mean	0.590	3	29	0.626

The results of Levene’s Test based on the mean yielded a significance value of 0.630, which is greater than 0.05 ( $p > 0.05$ ). This indicates that the data variances among the research groups are homogeneous. Consequently, the research data fulfil the requirements

for hypothesis testing using Two-Way Analysis of Variance (Two-Way ANOVA).

The hypothesis testing in this study was conducted using Two-Way ANOVA to determine the influence of the learning model and students' prior knowledge on

their mastery of electrical energy concepts. The results of the hypothesis testing are presented in Table 3 below.

Based on the Two-Way ANOVA analysis at a significance level of 0.05, the conclusions of this study demonstrate that first, the main effect of the learning model yielded a significance value of 0.000 ( $p < 0.05$ )

with an F-statistic of 190.465, indicating a significant difference in the mastery of electrical energy concepts between students taught with the Wordwall-assisted Problem-Based Learning (PBL) model and those taught with the conventional model.

**Table 3.** Hypothesis Testing Results: Two-Way ANOVA

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected model	4495.067 <sup>a</sup>	3	1498.356	84.767	0.000
Intercept	178129.717	1	178129.717	10077.382	0.000
Model_pemb	3366.693	1	3366.693	190.465	0.000
Kemp_awal	940.937	1	940.937	53.232	0.000
Model_pemb * kemp_awal	0.546	1	0.546	0.031	0.861
Error	494.933	28	17.676		
Total	188608.000	32			
Corrected total	4990.000	31			

a. R Squared = 0.901 (Adjusted R Squared = 0.890)

The experimental group achieved a higher post-test mean score, proving that the integration of PBL and Wordwall is significantly more effective than conventional methods. Second, the main effect of prior knowledge yielded a significance value of 0.000 ( $p < 0.05$ ) with an F-statistic of 53.232, confirming a significant difference in the final mastery of electrical energy concepts based on students' prior knowledge levels (High vs. Low), which indicates that a student's initial cognitive readiness significantly dictates their final learning outcomes.

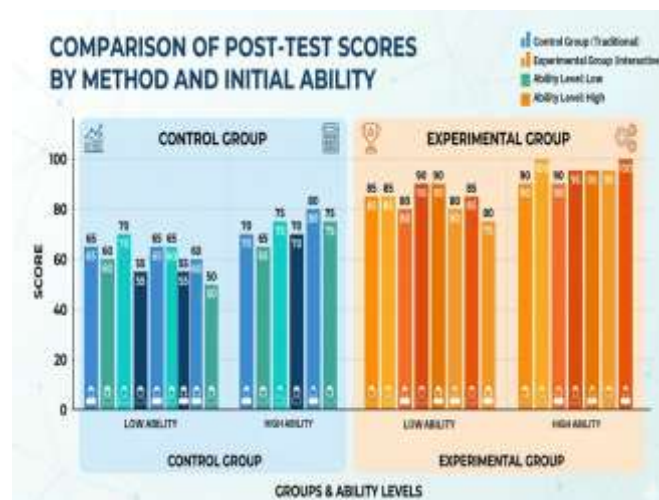
Third, the interaction effect between the learning model and prior knowledge yielded a significance value of 0.861 ( $p > 0.05$ ) with an F-statistic of 0.031, revealing that there is no significant interaction between the learning model and students' prior knowledge. This low F-value (0.031) underscores that the Wordwall-assisted PBL model consistently and uniformly enhances concept mastery across both high and low prior knowledge groups without being dependent on the students' initial ability levels.

*Discussion*

*The Influence of Wordwall-Assisted PBL Model on Electrical Energy Concept Mastery*

The results of the hypothesis testing using Two-Way Analysis of Variance (ANOVA) demonstrate that the learning model has a significant influence on the mastery of electrical energy concepts among fifth-grade elementary school students. The significance value for the learning model factor was found to be  $.000 < 0.05$ , indicating a significant difference in electrical energy concept mastery between students taught using the Wordwall-assisted Problem-Based Learning (PBL) model and those taught using the direct learning model. The comparison between control group and

experimental group post-test scores is presented in Figure 2 below.



**Figure 2.** Comparison of post test scores

The average concept mastery score of students in the experimental class was higher than that of the control class. Based on the data presented, there is a contrasting distribution of prior knowledge scores between the two research groups. In the Control Group, ten students in the low category had scores ranging from 50 to 70, while six students in the high category ranged from 65 to 80. Conversely, the Experimental Group demonstrated a superior initial baseline; ten students in the low category started with scores between 75 and 90, and seven students in the high category recorded very strong performances ranging from 90 to 100, including two students who achieved perfect scores.

This difference in indicates that the experimental group possessed higher initial cognitive readiness compared to the control group. Therefore, in further data analysis, the use of the N-Gain Score is highly

recommended to measure the effectiveness of the Wordwall-assisted Problem-Based Learning (PBL) treatment. By focusing on the normalized gain in scores, you can objectively prove the extent to which the digital media intervention stimulated student ability without being biased by their respective initial score differences.

These results can be explained by the fact that the PBL model provides students with opportunities to engage actively in the learning process through real-world problem-solving relevant to daily life. Students do not merely receive information passively but are encouraged to think critically, discuss, and construct knowledge independently (Tao et al., 2026). The support of Wordwall reinforces this process through game-based interactive activities that help students understand electrical energy concepts in a more concrete and enjoyable manner (Rudolphi-Solero et al., 2025).

These findings are consistent with previous research stating that PBL is effective in enhancing students' concept mastery and higher-order thinking skills (Astikawati et al., 2020; Fatmawati et al., 2025; Utama et al., 2025). Furthermore, the use of Wordwall has also been proven to increase engagement and learning outcomes among elementary school students (Arsih & Yunuarti, 2026; Khairani & Aloysius, 2023).

The significant improvement in concept mastery within the experimental group is inseparable from the synergy between the stages of the Problem-Based Learning (PBL) model and the interactive features of Wordwall (Charkova, 2024). During the problem orientation phase, Wordwall functions as a cognitive bridge, transforming abstract electrical energy concepts into more concrete visual representations (Cordero Valera et al., 2026).

In line with constructivist theory, this integration allows students to engage in independent exploration through interactive quizzes that provide immediate feedback (Hidayat & Syahfitri, 2023). This feedback plays a crucial role as digital scaffolding, particularly for students experiencing uncertainty in understanding current flow or electrical components. Furthermore, the gamification elements within Wordwall successfully reduce students' cognitive load, allowing their focus to remain directed toward the problem-solving tasks presented within the PBL syntax. This evidence proves that technology is not merely a supplementary tool, but rather an instrument that strengthens active engagement and information retention regarding complex scientific concepts (Çoban Sural & Yaşar Sağlık, 2024).

#### *Differences in Electrical Energy Concept Mastery Based on Students' Prior Knowledge*

The analysis results indicate that students' prior knowledge has a significant influence on their mastery of electrical energy concepts. The significance value for

the prior knowledge factor was  $.000 < 0.05$ , meaning there is a significant difference in electrical energy concept mastery between students with high prior knowledge and those with low prior knowledge (Brand et al., 2025).

Students with high prior knowledge demonstrated better mastery of electrical energy concepts compared to those with low prior knowledge (Von Rueden et al., 2023). This is evidenced by the mean score of students with high prior knowledge (95.00 in the experimental class and 72.50 in the control class) significantly outperforming those with low prior knowledge (82.50 and 60.50, respectively). This indicates that prior knowledge is a critical factor influencing students' learning success.

This finding supports Ausubel's learning theory, which states that a student's initial cognitive structure is a major determinant of meaningful learning success (West & Fensham, 1974). Students who already possess adequate prior knowledge find it easier to relate new information to existing concepts, making the learning process more effective. These research results are also consistent with the findings of (Putri et al., 2023) which state that prior knowledge plays a vital role in determining student learning outcomes.

Although prior knowledge has been proven to have an independent influence, these results also provide a foundation for the importance of implementing adaptive treatments (Tobias, 1994). This is because students with low prior knowledge require additional support to reach a threshold of conceptual mastery equivalent to their peers who possess higher cognitive readiness.

#### *Interaction Between Learning Model and Prior Knowledge on Electrical Energy Concept Mastery*

The results of the interaction test between the learning model and prior knowledge produced a significance value of  $0.000 < 0.05$ , indicating a significant interaction effect between the learning model and students' prior knowledge on mastery of electrical energy concepts. This statistical evidence confirms that the effectiveness of the Wordwall-assisted PBL model depends on students' initial cognitive readiness as presented in the following Figure 3 visualization.

As visualized in the Interaction Plot Figure 3, the slope of the experimental group's line is notably steeper than that of the control group. While students with low prior knowledge in the experimental class achieved a mean score of 82.50 (compared to 60.50 in the control class), the most significant acceleration occurred among students with high prior knowledge, who reached a peak mean score of 95.00 (compared to 72.50 in the control class). This finding suggests that while the model benefits all students, it provides a more pronounced

acceleration in learning outcomes for students with high prior knowledge. These students, possessing a more robust initial cognitive framework, are better equipped to navigate the complex problem-solving stages of PBL. The integration of Wordwall acts as a catalyst that optimizes their existing potential through high-level interactive challenges, effectively widening the achievement gap in a positive direction through personalized digital engagement.

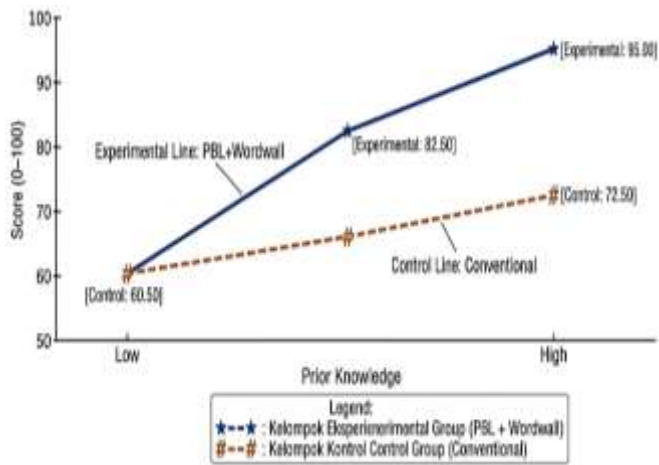


Figure 3. Interaction plot of learning model and prior knowledge on electrical energy concept mastery

Nevertheless, students with low prior knowledge also experienced a significant improvement. In this context, Wordwall serves as a "digital scaffolding" that bridges the gap between their limited prior knowledge and the complex scientific concepts being taught. The immediate feedback and gamification elements in Wordwall reduce the cognitive load for these students, preventing them from becoming overwhelmed by the PBL syntax.

These results underscore that the synergy between PBL and Wordwall creates a differentiated learning environment. While high-ability students are pushed toward mastery through exploration, low-ability students are supported through structured interactive cues. Therefore, the implementation of this model effectively addresses the diverse cognitive baselines in elementary classrooms, provided that teachers remain attentive to the specific scaffolding needs of each group. This interaction proves that technology-integrated PBL is not a "one-size-fits-all" solution but a dynamic intervention that interacts deeply with student characteristics to produce optimal scientific literacy.

**Conclusion**

Based on the findings, three primary conclusions are drawn. First, the Wordwall-assisted Problem-Based Learning (PBL) model significantly enhances fifth-grade

students' mastery of electrical energy concepts over conventional methods ( $F = 190.465$ ;  $p < 0.05$ ). Second, prior knowledge strongly determines learning outcomes ( $F = 53.232$ ;  $p < 0.05$ ), with high prior knowledge students consistently performing better. Third, no significant interaction exists between the learning model and prior knowledge ( $F = 0.031$ ;  $p = 0.861$ ), proving that the Wordwall-assisted PBL model is uniformly effective for all students regardless of their initial ability levels. Theoretically, this study expands modern constructivism by demonstrating that technology-based gamification inside PBL syntax serves as an effective digital scaffolding that bridges abstract science concepts for young learners. However, this study is limited by a small sample size ( $N = 33$ ) across only two public elementary schools, a brief treatment duration of four meetings, and a high dependence on stable digital infrastructure. Consequently, future research should replicate this model with larger, broader samples and test its efficacy on other abstract science topics or different educational levels. Investigating the integration of alternative digital platforms like Quizizz or Genially within problem-based frameworks is also highly recommended to enrich comparative technology-based pedagogy.

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**Author Contributions**

Conceptualization: M., P., and M.L.; Methodology: M. and M.L.; Software and statistical computation: M.; Validation: P. and M.L.; Investigation and fieldwork: M.; Data curation: M.; Writing - original draft preparation: M.; Writing - review and editing: P. and M.L.; Supervision: P. and M.L. All authors have read and agreed to the published version of the manuscript.

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**Conflicts of Interest**

The authors declare no conflict of interest. The web-based digital platform utilized in this study (Wordwall) was selected strictly as an instructional tool for educational and academic

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