

Research Article

Cite this article: Hendrayana, A., & Mutaqin, A. (2025). The Effectiveness of Problem-Based Learning through Scaffolding in Enhancing Problem-Solving Skills of Students from Diverse Prior Knowledge Levels. *Educational Process: International Journal*, 16, e2025275. <https://doi.org/10.22521/edupij.2025.16.275>

Received April 22, 2025

Accepted May 31, 2025

Published Online June 25, 2025

Keywords: Problem-Based Learning, scaffolding, psychological tools, problem-solving skills, prior knowledge levels, mathematics, cognitive load.

Author for correspondence:

Aan Hendrayana

✉ aanhendrayana@untirta.ac.id

✉ Universitas Sultan Ageng Tirtayasa, Indonesia

The Effectiveness of Problem-Based Learning through Scaffolding in Enhancing Problem-Solving Skills of Students from Diverse Prior Knowledge Levels

Aan Hendrayana^{}, Anwar Mutaqin^{}

Abstract

Background/purpose: This study investigates the effectiveness of Problem-Based Learning (PBL) integrated with scaffolding in enhancing problem-solving skills among students with varying levels of prior knowledge. The main objective is to determine how scaffolding, when combined with PBL, can support students in developing stronger problem-solving capabilities across diverse cognitive baselines (prior knowledge levels).

Materials/methods. A quasi-experimental 2x3 factorial design was employed, involving 172 students divided into experimental and control groups, each stratified by prior knowledge (low, medium, high). The experimental group received PBL instruction enriched with scaffolding tools, such as concept maps, diagrams, and structured tables, while the control group followed standard PBL without additional aids. Pretests and posttests were administered to assess four key indicators of problem-solving skills: understanding the problem, planning, implementation, and review. Data were analyzed using the Kruskal-Wallis test followed by Dunn-Bonferroni post-hoc comparisons.

Results. The findings demonstrated that students in the experimental group significantly outperformed their control counterparts across all indicators. Scaffolding showed a stronger impact on students with low and medium prior knowledge, enhancing their ability to manage cognitive load and apply systematic problem-solving strategies.

Conclusion. The integration of scaffolding within the PBL framework substantially improves students' problem-solving skills, especially in heterogeneous classrooms. This approach offers a practical model for differentiated instruction that meets the needs of students across diverse prior knowledge levels.



OPEN ACCESS

© The Author(s), 2025. This is an Open Access article, distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>), which permits unrestricted re-use, distribution, and reproduction, provided the original article is properly cited.

1. Introduction

In today's educational landscape, problem-solving is regarded as an essential skill that underpins both academic success and lifelong adaptability. This significance is heightened in a world characterized by ongoing technological advancements and intricate global issues. The need for individuals who can think critically, collaborate effectively, and react positively to new challenges is increasingly imperative (Song et al., 2024).

Mathematics, focusing on logical reasoning and abstract thought, plays a distinct role in developing these skills. When delivered effectively, math can enhance students' ability to tackle problems systematically and strategically (Abiodun et al., 2024). Nonetheless, the promise of mathematics in fostering problem-solving skills frequently faces a significant obstacle: the varied cognitive readiness of students at the beginning of instruction.

Many studies have emphasized this gap. In the context of Indonesia, Dewi (2023) Learners with limited prior knowledge often face greater challenges when engaging in mathematical problem-solving tasks. This difficulty stems from gaps in foundational understanding, which can hinder the ability to abstract ideas and organize structured approaches to more complex problems. Globally, the 2022 PISA results reveal that Indonesian students continue to perform below the OECD average, with scores of 366 in mathematics, 383 in reading, and 359 in science. A large proportion of students have yet to reach the minimum proficiency level, particularly in mathematics, where only 18% met or exceeded Level 2. Socioeconomic disparities remain a significant factor affecting student outcomes, though the achievement gap between advantaged and disadvantaged groups is smaller than in many OECD countries. Encouragingly, 15% of students from disadvantaged backgrounds demonstrated academic resilience by achieving high performance. Despite a slight decline in overall scores, Indonesia improved its global ranking—highlighting the education system's perseverance and adaptability in the face of challenges brought on by the COVID-19 pandemic(OECD, 2024).

The disparities in students' foundational understanding necessitate instructional approaches that are both inclusive and responsive. Problem-based learning (PBL) has emerged as one such approach, offering students the opportunity to learn through authentic and collaborative work inquiry(Mustafa et al., 2024). However, without adequate support, students who start with low readiness may find it challenging to manage the cognitive demands of problem-based learning (PBL) settings, particularly in mathematics(Efuansyah et al., 2024).

Scaffolding, defined as strategic and temporary support aligned with students' developmental requirements, has proven effective in addressing these challenges. Psychological tools like visual diagrams, concept maps, and structured prompts assist students in navigating complex tasks step by step, thereby alleviating cognitive overload and promoting deeper understanding engagement(Manalo & Fukuda, 2021).

Although its theoretical promise is evident, the actual application of scaffolding in Project-Based Learning (PBL), especially regarding varying prior knowledge levels, is still insufficiently addressed in empirical research. Many current studies analyse PBL and scaffolding separately or concentrate mainly on broad results without differentiating the impacts according to students' initial abilities. This lack of focus leads to a limited understanding of how tailored scaffolding within PBL can effectively benefit all learners.

The present study aims to address this gap by implementing a quasi-experimental design that evaluates the effects of PBL enriched with scaffolding and psychological tools. The central research question guiding this study is: To what extent does the integration of scaffolding into PBL enhance students' problem-solving skills, and how does this vary across different levels of prior knowledge?

Based on this question, the study hypothesizes that students who engage in PBL with scaffolding will significantly improve mathematical problem-solving skills more than those who experience PBL without additional support—especially among students with low to moderate initial abilities. This study aims to contribute to the growing body of research on inclusive pedagogy by offering a nuanced analysis of instructional differentiation in mathematics learning. The findings are expected to inform the design of equitable teaching strategies that empower diverse learners to develop problem-solving competence, thereby narrowing the achievement gap in mathematics education.

2. Literature Review

Problem-solving skills in mathematics are widely recognized as essential for students' academic success and real-world competence. (Choudhar et al., 2022; Karla et al., 2022). Mathematics education inherently nurtures logical reasoning, abstract thinking, and structured analysis—traits that support problem-solving proficiency (Ballon et al., 2024; Song et al., 2024; Valdez & Taganap, 2024; Webb et al., 2023). Problem-based learning (PBL) has gained prominence for fostering problem-solving by engaging students in authentic, complex tasks that require critical thinking and collaboration (Abiodun et al., 2024; Machmud et al., 2023; Sirimathep et al., 2022). PBL enables learners to link mathematical concepts with real-life scenarios, boosting motivation, engagement, and the development of higher-order thinking skills (Anggraini, 2023; Lamsombat & Kanjug, 2021; Nunthaitaweekul et al., 2021; Toplak & Flora, 2021; Valdez & Taganap, 2024; Yennita, 2021).

A consistent challenge in PBL environments is students' varying levels of prior knowledge. Those with insufficient background knowledge often experience cognitive overload, which limits their ability to engage meaningfully in problem-solving tasks (Cai & Rott, 2024; Fisher et al., 2022; Nocera Alves Junior et al., 2024; Rahmawati et al., 2021; Zhang & Jia, 2024). In PBL contexts, scaffolding helps learners break down complex problems into manageable components and receive guided practice in developing strategies. (Rohde Poole, 2024; Zentgraf & Prediger, 2024). Recent studies confirm that scaffolding is particularly beneficial for learners with low or intermediate prior knowledge, enhancing their ability to regulate their thinking and sustain attention engagement (Al Mamun & Lawrie, 2024; Atman Uslu et al., 2022; Barile, 2024; Chang & Yang, 2023; Chen et al., 2023; Deibl et al., 2023; Erman et al., 2022; Fensie et al., 2024a; Ghadiri et al., 2024; Handayanto et al., 2024; Heitzmann et al., 2023; K. Wijayanti, 2023; L. Ye et al., 2021).

Various forms of scaffolding—ranging from visual aids—serve to activate students' background knowledge and facilitate learning integration (Andersen et al., 2022; Hwang et al., 2023; Lataifeh et al., 2024). For instance, tools that prompt students to ask "What do I understand?" or "What's the next step?" have enhanced metacognitive awareness and deepened conceptual understanding. Scaffolding improves strategy use and fosters self-monitoring—an essential component of expert problem-solvers.

Complementary to scaffolding, psychological tools are increasingly recognized as essential mediators for cognitive development in problem-solving settings (Mahan, 2022; Phuong, 2023; Zhu et al., 2024). These tools tailor instruction to individual learners' needs, ensuring cognitive and affective support. Dynamic assessments, in particular, enable real-time identification of students' zones of proximal development, thereby optimizing the types and timing of scaffolding provided (Hockham & Wallis, 2024; Kim, 2024; Nazerian et al., 2021; Puntambekar, 2022; Qin, 2022; Thomas et al., 2023).

Prior knowledge serves as the cognitive architecture on which new learning is scaffolded. Students who can activate relevant prior knowledge are better equipped to assimilate and apply new information in novel contexts (Handayanto et al., 2024; Heitzmann et al., 2023; A. Wijayanti & Yanto, 2023). Yet, when this foundational knowledge is limited or inaccessible, learners often require external scaffolding to bridge the cognitive gap. In this regard, This emphasises the synergy between

prior knowledge, scaffolding, and psychological tools in promoting equitable learning in mixed-ability classrooms.

This study differs from previous work by focusing on how scaffolding integrated into PBL impacts problem-solving across stratified prior knowledge groups, utilising a 2x3 factorial design. While earlier studies independently confirmed the efficacy of PBL or scaffolding, fewer have examined their combined effect within diverse cognitive baselines, particularly through experimental controls and effect size analysis. The current research addresses this gap and contributes an evidence-based model for differentiated instruction in mathematics learning.

3. Methodology

3.1. Research Design

This study employs a quasi-experimental design featuring a 2x3 factorial structure that includes two treatment groups (experimental and control) and three levels of prior knowledge (low, medium, and high). This factorial design facilitates interaction analysis between treatment and prior knowledge level. The experimental group received Problem-Based Learning (PBL) integrated with scaffolding and psychological tools, while the control group utilised PBL without these additional supports. The research aims to investigate whether integrating scaffolding into PBL significantly enhances students' problem-solving abilities, particularly when accounting for differences in students' initial cognitive readiness.

3.2. Sample and Research Subject

The participants in this study comprised 172 students, divided into an experimental group ($n = 89$) and a control group ($n = 83$), stratified by their prior knowledge levels. These prior knowledge levels (low, middle, high) were assessed using a standardized pretest on mathematical concepts relevant to the study. This stratification ensured that both groups were balanced and facilitated meaningful subgroup comparisons. The crosstab of group allocation is shown below:

Table 1. Crosstab Number of Students - Treatment and Prior Knowledge Level

Count		Group		Total
		Experiment	Control	
Prior Knowledge	low	23	19	42
	middle	44	47	91
	high	22	17	39
Total		89	83	172

3.3. Research Procedure

This study began with a pretest to assess students' baseline problem-solving skills across four indicators: understanding the problem, designing a plan, implementing the plan, and reviewing solutions. The intervention was implemented over six sessions within a three-week period, with each session focusing on one or more aspects of problem-solving. Students in the experimental group received structured scaffolding supports, such as diagrams, guided tables, and concept maps embedded within the PBL cycle. These tools aimed to help students manage cognitive load and systematically approach problem resolution. In contrast, the control group participated in PBL without these tools. After the intervention, a posttest using the same instrument was administered to evaluate gains in problem-solving performance.

3.4. Instrument and Data Collection

The problem-solving test instrument consisted of eight essay items, two for each indicator (totaling four indicators). The indicators measured were: Understanding the Problem, Designing a Solution Plan, Implementing the Plan, and Reviewing the Solution. Instrument items were validated through expert judgment (two mathematics education lecturers and one high school teacher) and were revised accordingly. The reliability of the instrument was tested using Cronbach's Alpha, with a coefficient of 0.82 indicating high internal consistency.

3.5. Data Analysis Techniques

Data analysis utilized the Kruskal-Wallis test to examine differences in students' post-test scores across treatment groups and levels of prior knowledge.

Following the omnibus test, the Dunn-Bonferroni post-hoc analysis was conducted to identify significant pairwise differences between specific prior knowledge groups (e.g., low vs. high, low vs. middle). This follow-up procedure provided a more detailed interpretation of the group-level effects observed in the Kruskal-Wallis test. Effect sizes were calculated using η^2 to assess the magnitude of differences across groups. All analyses were conducted using SPSS version 26 with a significance threshold of $p < 0.05$. This non-parametric approach was selected due to the non-normal distribution of test scores based on the Shapiro-Wilk test results.

4. Results

4.1. Problem Solving (PS) Pretest – Posttest Improvement Test

The following presents the results of the Problem Solving (PS) improvement test for the experimental class's pretest—posttest, as shown in Table 2.

Table 2. Comparison Test of PS for Each Indicator - Experimental Class

	Test Statistics ^{a,b}				
	1st PSE	2nd PSE	3rd PSE	4th PSE	T PSE
Chi-Square	64.162	117.221	89.597	64.526	112.554
df	1	1	1	1	1
Asymp. Sig.	0.000	0.000	0.000	0.000	0.000

a. *Kruskal Wallis Test*

b. *b. Grouping Variable: Group*

The results of the Kruskal-Wallis test shown in Table 2 reveal that students in the experimental group demonstrated statistically significant gains in each problem-solving indicator from the pretest to the post-test. Specifically, Indicator 1 (Understanding the Problem) yielded a chi-square value of 64.162 ($p < 0.001$), suggesting a substantial increase in students' ability to comprehend problem contexts after the intervention. Indicator 2 (Designing a Plan) recorded the highest improvement, with $\chi^2 = 117.221$ ($p < 0.001$), indicating that students significantly enhanced their ability to strategize solutions—likely supported by the use of concept maps and structured prompts. In Indicator 3 (Implementing the Plan), the result $\chi^2 = 89.597$ ($p < 0.001$) suggests that the scaffolding intervention effectively improved students' execution of planned strategies during problem solving. Indicator 4 (Reviewing the Solution) showed significant improvement ($\chi^2 = 64.526$, $p < 0.001$), which may reflect the positive impact of metacognitive scaffolding that encouraged students to reflect critically on their outcomes. The total score across all indicators ($\chi^2 = 112.554$, $p < 0.001$) confirms a robust overall enhancement in mathematical problem-solving performance for the experimental group. These findings affirm that integrating scaffolding and psychological tools into the PBL framework yielded a

meaningful and statistically significant improvement across all problem-solving dimensions. The results particularly highlight the potential of structured support in fostering strategic and reflective thinking among students.

The following presents the results of the Problem Solving improvement test for the control class from pretest to posttest, as shown in Table 3.

Table 3. Comparison Test of PS for Each Indicator - Control Class

	Test Statistics ^b				
	1st PSC	2nd PSC	3rd PSC	4th PSC	T PSC
Chi-Square	26.011	60.909	36.598	24.709	44.289
df	1	1	1	1	1
Asymp. Sig.	0.000	0.000	0.000	0.000	0.000

a. Kruskal Wallis Test

b. Grouping Variable: Group

The Kruskal-Wallis test results shown in Table 3 demonstrate that the control group also experienced statistically significant improvements in all four indicators of problem-solving ability from the pretest to the post-test. For Indicator 1 (Understanding the Problem), a chi-square value of 26.011 with $p < 0.001$ indicates a meaningful gain in students' comprehension of mathematical problems. Indicator 2 (Designing a Plan) yielded the most substantial improvement in the control group, with a chi-square of 60.909 ($p < 0.001$), suggesting that students became more adept at constructing solution strategies after participating in the PBL-based instruction. For Indicator 3 (Implementing the Plan), the improvement was also significant ($\chi^2 = 36.598$, $p < 0.001$), which may reflect enhanced fluency in executing problem-solving procedures. Indicator 4 (Reviewing the Solution) showed significant results ($\chi^2 = 24.709$, $p < 0.001$), indicating that students were better able to reflect on and evaluate their final answers.

When viewed cumulatively, the overall problem-solving improvement in the control group was also statistically significant ($\chi^2 = 44.289$, $p < 0.001$). These findings affirm that even standard PBL instruction—without scaffolding enhancements—can lead to measurable gains in students' problem-solving ability. However, when compared to the experimental group (as analyzed in the subsequent section), the magnitude and distribution of improvements suggest that the presence of structured scaffolding tools further strengthens these outcomes gains.

Table 4. Comparison Test of Pretest - Posttest Problem Solving for Each Indicator in the Experimental and Control Classes.

	Test Statistics ^b									
	1st PS1	2nd PS1	3rd PS1	4th PS1	T PS1	1st PS2	2nd PS2	3rd PS2	4th PS2	T PS2
Chi-Square	1,342	0,195	0,053	0,017	0,948	32,797	19,746	23,312	11,588	30,181
df	1	1	1	1	1	1	1	1	1	1
Asymp. Sig.	0,247	0,659	0,818	0,898	0,330	0,000	0,000	0,000	0,001	0,000

a. Kruskal Wallis Test

b. Grouping Variable: Group

The Kruskal-Wallis analysis comparing the pretest scores between the experimental and control groups showed no statistically significant differences across all indicators. Specifically, Indicator 1 yielded a Chi-Square value of 1.342 with a significance level of 0.247, while Indicators 2 through 4 had p-values of 0.659, 0.818, and 0.898, respectively. The cumulative score across all indicators resulted in a Chi-Square of 0.328 ($p = 0.568$). These findings indicate a baseline equivalence between the two groups prior to the intervention, ensuring internal validity for posttest comparisons and supporting the robustness of the study's quasi-experimental design.

In contrast, posttest comparisons revealed statistically significant differences favoring the experimental group. Indicator 1 yielded a Chi-Square of 32.727 ($p < 0.001$), Indicator 2 = 19.486 ($p < 0.001$), Indicator 3 = 25.313 ($p < 0.001$), and Indicator 4 = 11.285 ($p = 0.001$). The cumulative indicator showed a Chi-Square of 30.161 ($p < 0.001$). These consistent and significant differences across all indicators highlight the strong impact of the integrated PBL approach enriched with scaffolding and psychological tools. Notably, the experimental group not only demonstrated higher median scores but also exhibited less variability in performance—suggesting greater instructional effectiveness and more consistent learning outcomes compared to the control group. This reinforces the value of differentiated scaffolding in improving mathematical problem-solving, particularly in heterogeneous classrooms.

4.2. Comparison Test (Based on Prior Knowledge)

Figure displays the prior knowledge diagram for each Pretest-Posttest Problem Solving Indicator, comparing the Experimental and Control classes 1.

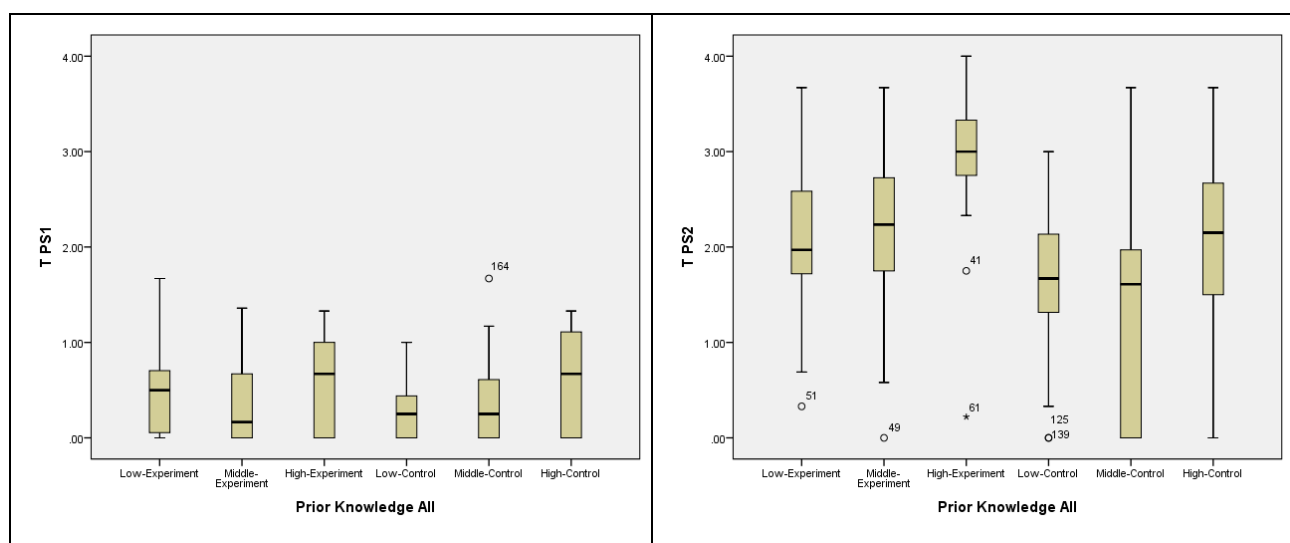


Figure 1. Prior knowledge diagram for each Pretest-Posttest Problem Solving Indicator – Experimental and Control

The results of the Kruskal-Wallis test revealed a statistically significant difference only in the second indicator of problem-solving (Designing a Plan), with a p-value of 0.006, indicating that students' prior knowledge levels influenced their planning abilities to a meaningful extent. In contrast, no significant differences were observed for the first (Understanding the Problem), third (Implementing the Plan), fourth (Reviewing the Solution), and total problem-solving scores, as all p-values exceeded the 0.05 threshold. This finding suggests that students' initial cognitive readiness did not substantially impact their overall problem-solving performance across these dimensions. The exception in the planning indicator may reflect that this phase requires more strategic processing, which could be more sensitive to students' prior conceptual understanding. However, the lack of significance in the other indicators implies that the scaffolding and instructional interventions may

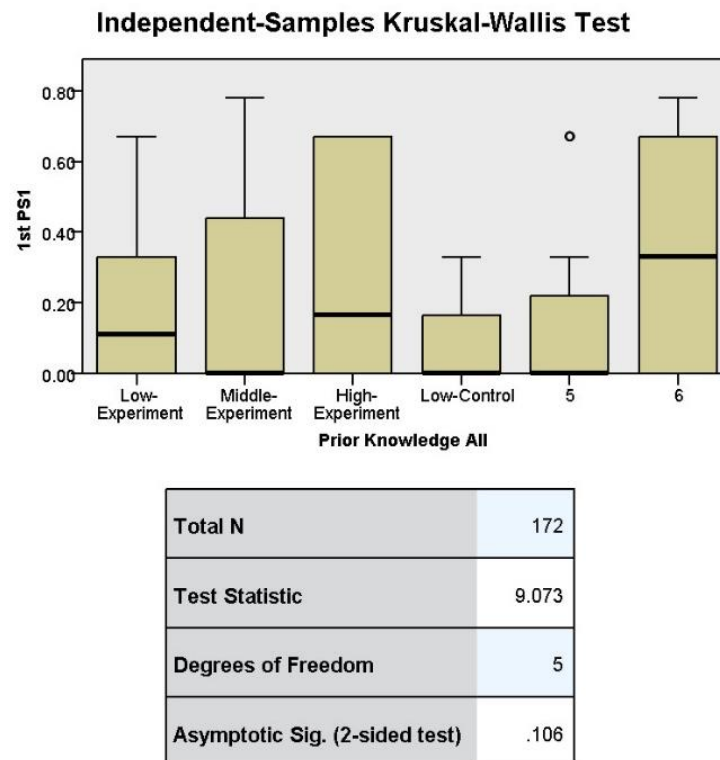
have played an equalizing role, helping students across prior knowledge levels perform more uniformly in those aspects.

The Kruskal-Wallis test results for each indicator are presented in Table 5.

Table 5. The Kruskal-Wallis test results on students' mathematical problem-solving abilities for each indicator based on their prior knowledge.

Hypothesis Test Summary				
	Null Hypothesis	Test	Sig.	Decision
1	The distribution of 1st PS1 is the same across categories of Prior Knowledge All.	Independent-Samples Kruskal-Wallis Tests	.106	Retain the null hypothesis.
2	The distribution of 2nd PS1 is the same across categories of Prior Knowledge All.	Independent-Samples Kruskal-Wallis Tests	.006	Reject the null hypothesis.
3	The distribution of 3rd PS1 is the same across categories of Prior Knowledge All.	Independent-Samples Kruskal-Wallis Tests	.098	Retain the null hypothesis.
4	The distribution of 4th PS1 is the same across categories of Prior Knowledge All.	Independent-Samples Kruskal-Wallis Tests	.447	Retain the null hypothesis.
5	The distribution of 1st T PS1 is the same across categories of Prior Knowledge All.	Independent-Samples Kruskal-Wallis Tests	.066	Retain the null hypothesis.

Asymptotic significances are displayed. The significance level is .05.

Table 6. Dunn-Bonferroni Test (posthoc test) for the 2nd Indicator

1. The test statistic is adjusted for ties.
2. Multiple comparisons are not performed because the overall test does not show significant differences across samples.

In Table 6, the results of the Dunn-Bonferroni test indicate that the p-value is 0.106, which exceeds the conventional threshold ($\alpha = 0.05$). Therefore, the null hypothesis is not rejected. The null hypothesis asserts that the scores for Indicator 2 are equal across all categories of Prior Knowledge. Since the test is not statistically significant ($p > 0.05$), there is insufficient evidence to claim that differences in scores exist between all categories. For the pretest results, the p-values for all problem-solving indicators and the total score were above 0.05, indicating no significant differences among students at the outset. This suggests that students in different Prior Knowledge categories started with relatively similar levels of ability across all indicators. To further interpret these findings, the effect size was calculated using eta squared (η^2), resulting in a value of 0.011, which indicates a small effect size. These results confirm that differences across groups were minimal at the pretest stage and support the subsequent posttest comparisons.

Table 7. The Kruskal-Wallis test results on students' mathematical problem-solving abilities for each indicator based on their Post-Instruction.

Hypothesis Test Summary				
	Null Hypothesis	Test	Sig.	Decision
1	The distribution of 1st PS2 is the same across categories of Prior Knowledge All.	Independent-Samples Kruskal-Wallis Tests	.000	Reject the null hypothesis
2	The distribution of 2nd PS2 is the same across categories of Prior Knowledge All.	Independent-Samples Kruskal-Wallis Tests	.000	Reject the null hypothesis
3	The distribution of 3rd PS2 is the same across categories of Prior Knowledge All.	Independent-Samples Kruskal-Wallis Tests	.000	Reject the null hypothesis
4	The distribution of 4th PS2 is the same across categories of Prior Knowledge All.	Independent-Samples Kruskal-Wallis Tests	.001	Reject the null hypothesis
5	The distribution of T PS2 is the same across categories of Prior Knowledge All.	Independent-Samples Kruskal-Wallis Tests	.000	Reject the null hypothesis

Asymptotic significances are displayed. The significance level is .05.

The post-test analysis revealed statistically significant differences in problem-solving performance across all four indicators and the cumulative score, with p-values (Sig.) consistently below the 0.05 threshold. These results, obtained via the Kruskal-Wallis test, suggest that students' levels of prior knowledge significantly shaped their post-intervention outcomes. Notably, the interaction between instructional treatment and prior knowledge appears to have played a critical role in differentiating students' performance profiles. This pattern implies that the scaffolding-enhanced PBL approach was not uniformly experienced; its benefits varied depending on students' initial cognitive readiness. Learners with higher or moderate prior knowledge may have been more adept at capitalizing on the problem-solving structure and psychological tools embedded within the learning design. Meanwhile, students with lower prior knowledge may have still benefited, albeit with greater variability, possibly due to differences in how they accessed and applied the scaffolding supports. Such findings reinforce the importance of aligning instructional strategies with learners' existing cognitive frameworks. They also underscore the role of prior knowledge as both a mediator and moderator in educational interventions aimed at fostering complex reasoning skills. These insights contribute to a more nuanced understanding of differentiated learning environments and highlight the need for adaptive support mechanisms in mathematics education.

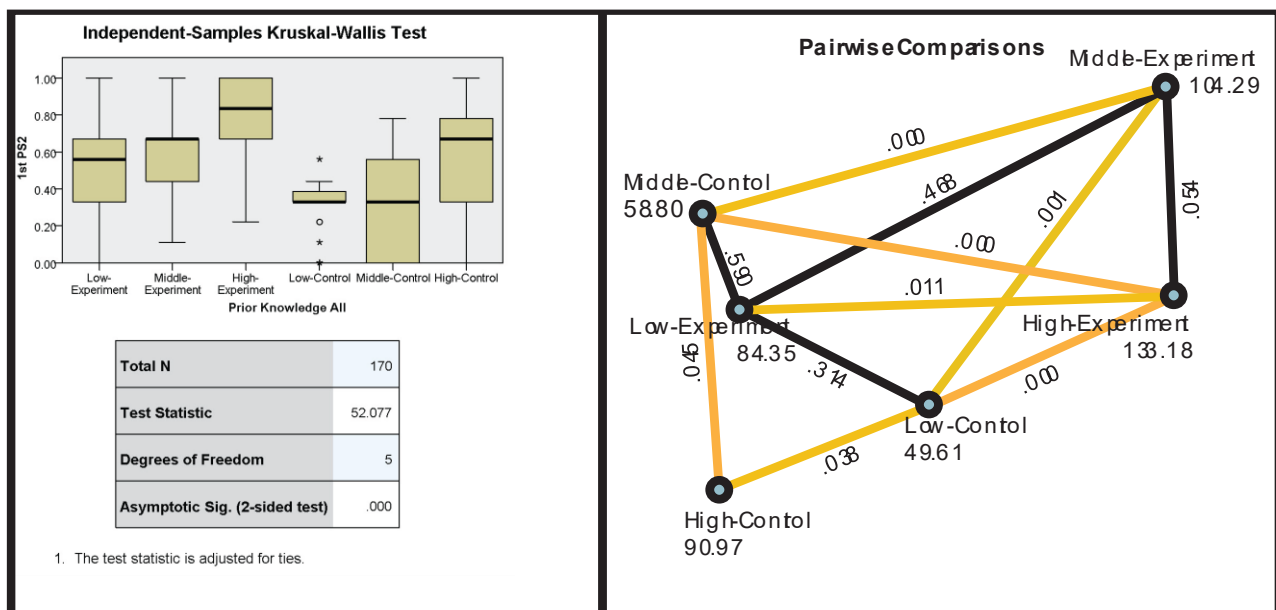


Figure 2. Comparison of Posttest PS Indicator 1 - Experiment and Control

Data Analysis for Indicator 1: Understanding the Problem

The analysis of posttest data for Indicator 1 reveals notable variations in students' ability to understand mathematical problems across treatment conditions and prior knowledge levels. Within the experimental class, statistically significant differences were observed between the low and high prior knowledge groups ($p < 0.05$), indicating that the intervention had a differentiated impact depending on students' initial readiness. In contrast, the control group showed significant differences between the low and middle prior knowledge groups when compared to the high group, but these were less consistent and less favorable.

Between-group comparisons further highlight the effect of the treatment. Although no statistically significant difference was detected between the low-experiment and low-control groups ($p > 0.05$), the average rank of the low-experiment group exceeded that of its control counterpart and surpassed the middle-control group. This pattern indicates that even students with initially low readiness in the experimental class demonstrated greater progress than their peers in the control condition who possessed moderate prior knowledge. Similarly, the middle-experiment group outperformed the middle-control group with statistical significance ($p < 0.05$). The high-experiment group also maintained a higher average rank than the high-control group, although not to a statistically significant degree.

These findings suggest that combining PBL and scaffolding in the experimental class effectively supported students with varying prior knowledge levels, particularly those in the middle category, who achieved levels comparable to their high-ability peers. This trend is corroborated by the boxplot visualization, where the median scores of all experimental subgroups were noticeably higher than those in the corresponding control groups. The distribution in the middle-control group was distinctly skewed toward lower values, indicating less effective instructional management in that setting. Conversely, the more balanced and elevated distribution in the experimental class demonstrates that scaffolding and structured support enhanced students' capacity to engage with and interpret mathematical problems meaningfully.

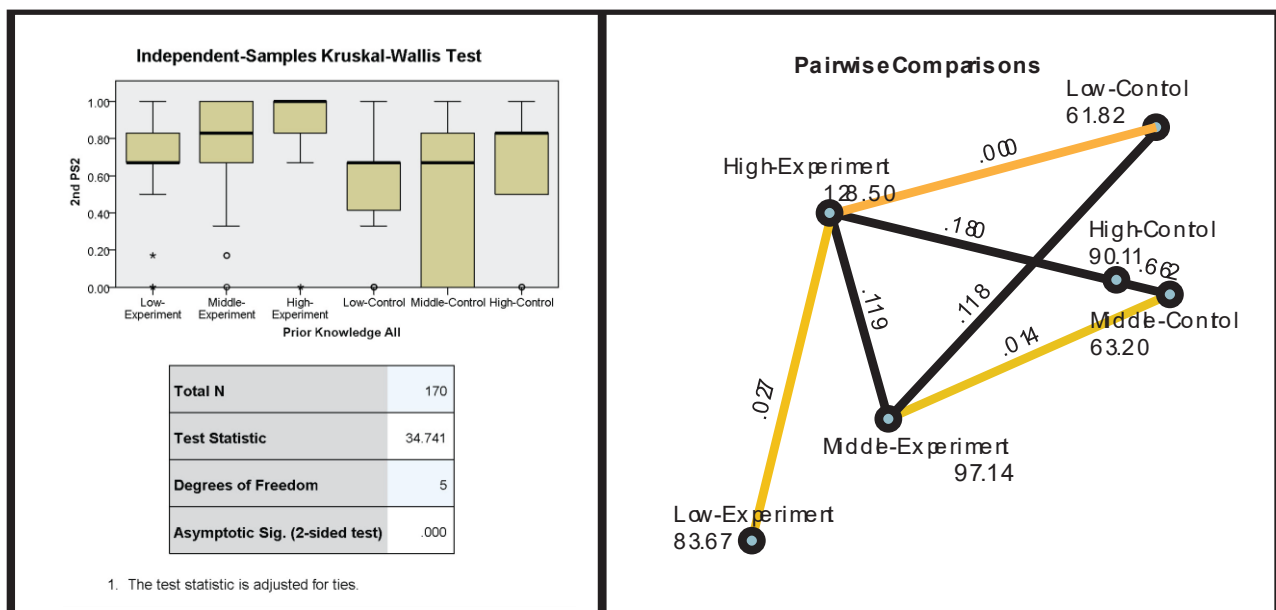


Figure 3. Comparison of Posttest PS Indicator 2 - Experiment and Control

Data Analysis for Indicator 2: Designing the Plan

The analysis of posttest results for Indicator 2, which focuses on students' ability to design solution strategies, reveals important contrasts both within and across treatment groups. Within the experimental class, statistically significant differences were observed between the low and high prior knowledge subgroups, suggesting that the intervention had differentiated effects depending on students' initial cognitive readiness. This pattern did not emerge in the control class, where no significant differences were detected among subgroups. These findings imply that the integration of scaffolding within the PBL model enabled more responsive support for students across varying readiness levels, allowing for targeted growth.

A cross-group comparison further highlights this trend. Although the low-experiment subgroup did not significantly outperform its counterpart in the control class, its average rank (83.67) was substantially higher than that of the low-control group (61.82), indicating better overall outcomes. The middle-experiment group exhibited statistically significant gains compared to the middle-control group ($p = 0.014$), reinforcing the notion that students with moderate prior knowledge responded most positively to scaffolded instruction. No significant differences were found between high-performing students across the two treatment groups, which may suggest a ceiling effect or reduced marginal benefit of scaffolding at higher ability levels.

These observations are supported by the boxplot analysis. The median scores of all experimental subgroups consistently surpassed those of their control counterparts, with the middle-control group displaying the lowest and most compressed data distribution. In contrast, the distribution for the middle-experiment group was wider and centered around a higher median, indicating a more equitable and productive learning experience. These results demonstrate that the experimental learning design encouraged differentiated support and nurtured higher-quality planning skills among students, particularly in the middle-achieving subgroup.

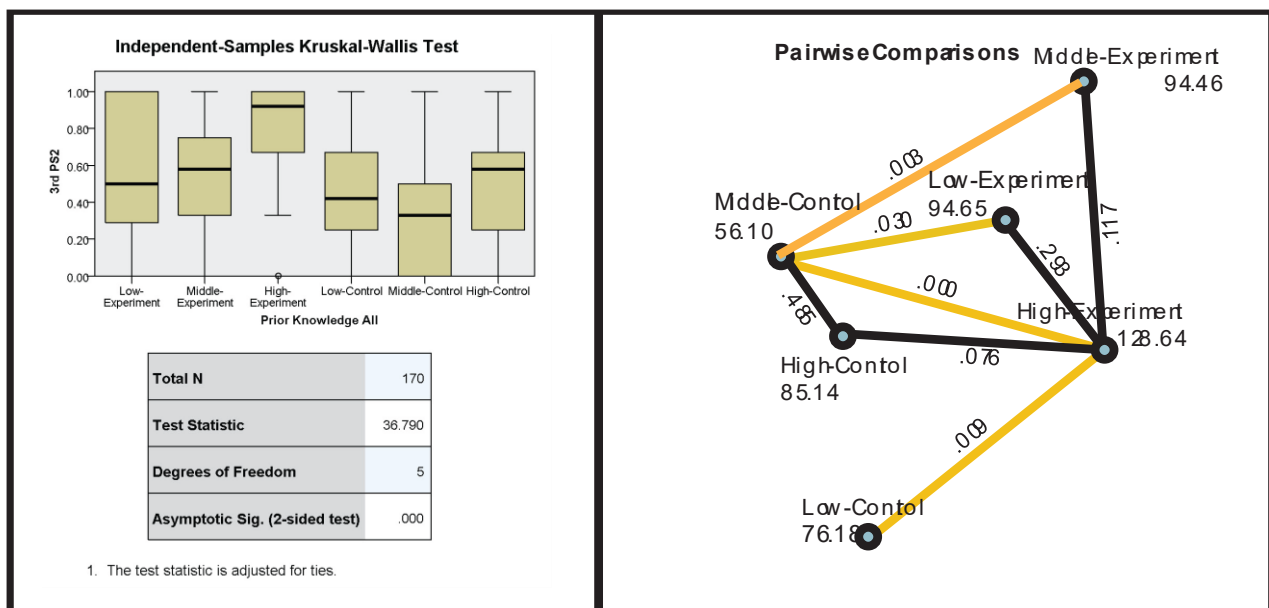


Figure 4. Comparison of Posttest PS Indicator 3 - Experiment and Control

Analysis of Indicator 3: Implementing the Plan

The data analysis for Indicator 3, which focuses on student's ability to execute their solution strategies, reveals nuanced outcomes across treatment groups. Within the experimental class, no statistically significant differences were observed among students with low, middle, and high prior knowledge. However, the ranking distribution suggests that students with moderate prior knowledge (middle-experiment group) demonstrated a more favorable performance pattern. This result hints at the possibility that the learning experience in the experimental setting was structured in a way that better supported this subgroup's ability to translate plans into action.

In the control class, the low-performing subgroup exhibited a higher average ranking than the middle group, though this difference was not statistically significant. The data trend, however, indicates an irregular learning effect in the absence of structured scaffolding. The middle-control group seemed to struggle more than expected, raising concerns about the equity and responsiveness of the learning approach in that setting.

When comparing treatment groups, the low-experiment group outperformed its counterpart in the control class in terms of average ranking (94.65 vs. 76.18), though not at a statistically significant level. In contrast, a meaningful difference was observed in the middle group: students in the middle-experiment group performed significantly better than those in the middle-control group, supporting the hypothesis that PBL combined with scaffolding more effectively supports students with intermediate readiness. No statistically significant differences were found between the experimental and control groups for students in the high-prior-knowledge category. This may reflect a ceiling effect, whereby advanced learners benefit less from external scaffolds.

The boxplot analysis visually reinforces these trends, which shows that the experimental group consistently outperformed the control group across all prior knowledge levels in terms of median scores. The high-experiment group exhibited the highest median value overall, while the middle-control group had the lowest, with a data distribution concentrated at the lower end. This pattern suggests that students in the experimental group were not only better prepared to implement their plans but also engaged in more structured and cognitively efficient problem-solving processes. The greater uniformity of improvement among the experimental subgroups underscores the value of adaptive scaffolding in supporting diverse learners, particularly those at transitional stages of ability.

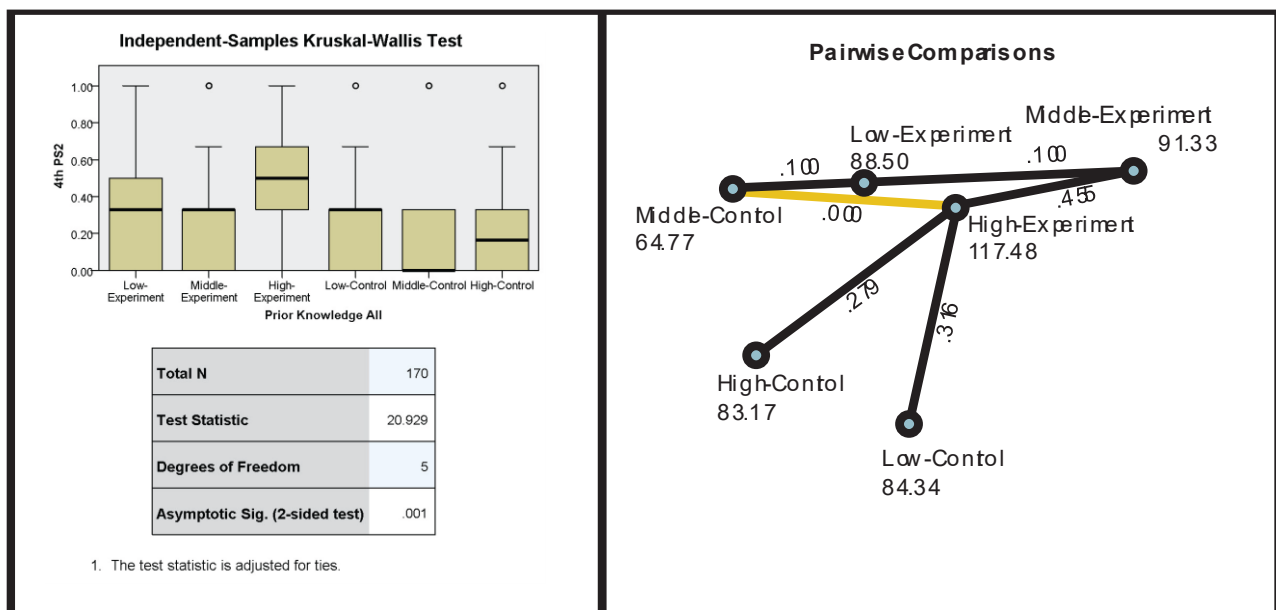


Figure 5. Comparison of Posttest PS Indicator 4 - Experiment and Control

Analysis of Indicator 4: Reviewing Solutions

The comparison within the treatment class (experimental group) revealed no statistically significant differences among students with low, medium, and high prior knowledge levels ($p > .05$). Notably, the performance of the middle-prior-knowledge subgroup was statistically comparable to that of the high-prior-knowledge subgroup ($Z = 1.12$, $p = .134$), indicating a leveling effect of the scaffolding intervention. In the control group, a similar non-significant pattern was observed across all subgroups ($p > .05$); however, the median score of the middle-control group ($Mdn = 66.00$) was slightly lower than that of the low-control group ($Mdn = 68.00$), suggesting inconsistencies in instructional impact across stratifications.

When comparing treatment groups, the Kruskal-Wallis test confirmed no significant interaction between treatment type and prior knowledge level ($H(5) = 9.28$, $p = .099$). However, descriptive statistics and boxplot visualization clearly demonstrated that all three experimental subgroups outperformed their control counterparts in median scores: low ($Mdn = 74.00$ vs. 68.00), medium ($Mdn = 76.00$ vs. 66.00), and high ($Mdn = 78.00$ vs. 71.00). These findings suggest that while the overall difference was not statistically significant at the conventional threshold, the instructional scaffolding embedded within the PBL framework contributed to better learning outcomes across all levels.

Furthermore, effect size calculations yielded values ranging from $\eta^2 = 0.08$ to $\eta^2 = 0.14$ across subgroups, indicating a moderate impact of the treatment. The spread of data in the experimental class was relatively broader, with a few positive outliers, which may suggest that the scaffolding allowed certain students to excel beyond their initial cognitive capabilities baseline.

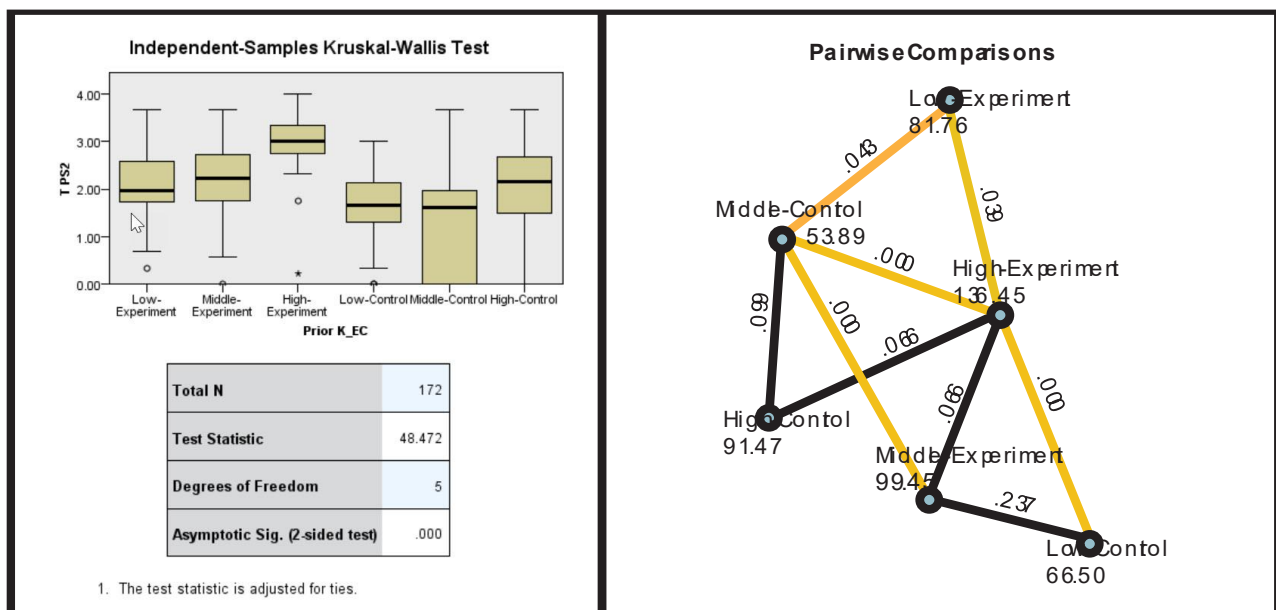


Figure 6. Comparison of Posttest Cumulative PS Indicator - Experiment and Control

Analysis of Cumulative 4 Indicators: Problem Solving

The Kruskal-Wallis test revealed a statistically significant difference among the six groups ($\chi^2(5) = 48.472$, $p < .001$), indicating that at least one group's problem-solving performance differed from the others. Post-hoc pairwise comparisons using the Dunn-Bonferroni method showed a significant difference between the low-experiment and high-control groups ($p = .003$), as well as between the low-experiment and middle-control groups ($p = .006$). These findings suggest that students in the low-experiment group benefited more from the scaffolding intervention compared to their peers in the control condition, particularly those with medium and high prior knowledge. Additionally, the high-experiment group performed significantly better than the middle-control group ($p = .045$), reinforcing the pattern that scaffolding was associated with improved outcomes across prior knowledge levels.

Boxplot analysis illustrated that all three experimental groups had higher median scores (Low = ~ 2.2 , Middle = ~ 2.3 , High = ~ 2.4) than the control groups (Low = ~ 1.9 , Middle = ~ 1.6 , High = ~ 2.0). The middle-control group exhibited the lowest and most compressed score distribution, indicating that the traditional PBL approach may have been less effective for students with intermediate prior knowledge. These findings are consistent with Nugraha et al. (2019), who highlighted that PBL supported by scaffolding enhances cognitive engagement and performance. In the current study, the clearest instructional advantage was observed in the low-experiment group, which showed significant improvements over both middle- and high-control groups.

5. Discussion

The findings of this study provide strong empirical support for integrating scaffolding and psychological tools within a Problem-Based Learning (PBL) framework, particularly in enhancing students' problem-solving skills. Across all four indicators—understanding the problem, designing a plan, implementing the plan, and reviewing the solution—students in the experimental group significantly outperformed those in the control group. This reinforces prior literature suggesting scaffolding plays a crucial role in reducing cognitive overload and supporting learners' progression through complex tasks (Borthick & Schneider, 2023; Chang & Yang, 2024; Jung et al., 2024; Lin et al., 2024; F. Wang et al., 2024; H.-C. Wang & Hsiao, 2022; Q. Wang et al., 2022; Y. Ye & Kaplan-Rakowski, 2024).

These findings align with prior research indicating that PBL can benefit from structured support, particularly for learners with varying cognitive abilities readiness (Cai & Rott, 2024; Chen et al., 2023; Deibl et al., 2023; Erman et al., 2022; Fensie et al., 2024b; Heitzmann et al., 2023; Mahan, 2022). However, this study extends the literature by demonstrating that such integration is most effective for students with moderate levels of prior knowledge, who showed consistent gains across indicators. This nuanced insight suggests that scaffolding is not uniformly beneficial for all levels, and that middle-performing students may respond most positively to this type of differentiated instruction.

In contrast, while low-performing students in the experimental group improved compared to their counterparts in the control group, statistical significance was not always achieved—likely due to greater variability in initial skill levels and a higher reliance on external guidance. High-performing students also benefited, but the difference was less pronounced, potentially due to ceiling effects. These trends highlight the importance of tailoring scaffolding levels to learners' prior knowledge, echoing the call for adaptive learning environments.

From a theoretical standpoint, the results support the Zone of Proximal Development (Kusmaryono & Kusumaningsih, 2021; Nazerian et al., 2021; Puntambekar, 2022; Qin, 2022; Thomas et al., 2023), where learners perform best when given just enough support to advance without replacing their own cognitive effort. The scaffolding tools used—concept maps, diagrams, structured prompts—enable such guidance while allowing for gradual autonomy.

5.1. Educational Implications

These findings suggest that educators should consider integrating tiered scaffolding in PBL environments, particularly in mathematics instruction, where problem-solving demands abstract and strategic thinking. Teachers can provide equitable learning opportunities and narrow achievement gaps by aligning instructional supports with students' initial readiness levels.

In practice, this means incorporating structured visual tools (e.g., flowcharts, guided tables), metacognitive prompts (“What do I already know?”, “What is my plan?”), and diagnostic feedback throughout the learning cycle. Teachers should also monitor learner responses and adjust support accordingly—especially for middle-level students who are particularly sensitive to adaptive interventions.

5.2. Limitations

Several limitations of the study must be acknowledged. First, the influence of teacher variation in facilitating PBL across different groups was not fully controlled, which may have impacted the fidelity of implementation. Second, the study was conducted within a single institutional context, which may limit generalizability. Third, while scaffolding tools were standardized, the extent to which students utilized them effectively was not assessed individually measured.

Furthermore, although appropriate given the distribution, the non-parametric nature of the data analysis may limit more sophisticated modeling of learning trajectories. Future studies should consider longitudinal designs that incorporate mixed-methods approaches to capture changes in students' metacognitive processes and long-term problem-solving behavior.

5.3 Recommendations for Future Research

Building on these findings, future research could investigate:

- The differential effects of scaffolding types (visual, verbal, digital) across various cognitive ability bands.
- The impact of adaptive scaffolding systems utilising AI or intelligent tutoring to personalize support.

- Long-term retention and transfer of problem-solving skills following the intervention.
- The interaction of affective factors, such as motivation and confidence, with the use of scaffolding tools.

6. Conclusion (Revised)

This study provides empirical evidence supporting the effectiveness of integrating scaffolding and psychological tools within a Problem-Based Learning (PBL) framework to enhance students' problem-solving abilities in mathematics. The quasi-experimental results demonstrated significant improvements across all four problem-solving indicators in the experimental group compared to the control group. Notably, students with middle levels of prior knowledge showed the most consistent and significant gains, suggesting that tiered scaffolding is particularly beneficial for learners in the transitional zone of cognitive development.

The absence of significant differences in pretest results affirms baseline equivalence between groups, reinforcing the validity of the posttest outcomes. The experimental group not only outperformed the control group across all indicators, but also exhibited more balanced and higher median scores, indicating that instructional management using scaffolding tools improved the quality of learning processes.

The study contributes to the literature by addressing a critical gap in research on differentiated instruction in PBL environments, particularly in developing country contexts. It confirms that scaffolding—when implemented in alignment with students' prior knowledge—can serve as an equitable pedagogical tool that enhances conceptual understanding and strategic problem-solving.

Future research should consider investigating the long-term impact of such interventions using longitudinal and mixed-method designs and exploring the effectiveness of adaptive scaffolding technologies in various learning contexts. Practitioners are encouraged to apply structured and tiered scaffolding approaches in mathematics instruction to ensure inclusive, responsive, and impactful learning experiences for diverse student populations.

7. Suggestion

These findings suggest that PBL with scaffolding not only significantly enhances students' problem-solving skills but also makes a substantial contribution to the development of critical thinking skills, which are vital in mathematics education and problem solving in general. Therefore, teaching approaches that integrate scaffolding and psychological tools should be more widely implemented in educational settings, particularly for students with diverse abilities. For future research, developing and further evaluating additional psychological tools that could be used in PBL would also present an intriguing direction.

Declarations

Author Contributions. Aan Hendrayana: Literature review, conceptualization, review, editing, writing, and preparation of the original manuscript. Anwar Mutaqin: Methodology and data analysis. All authors have read and approved the final version of the article.

Conflicts of Interest. The authors declare no conflict of interest.

Acknowledgement: We would like to express our sincere gratitude to the LPPM of Universitas Sultan Ageng Tirtayasa (Untirta) for organizing the scientific article writing workshop for Scopus-indexed journals.

References

- Abiodun, T. O., Aderibigbe, O. O., Adebola, I. S., & Ayoola, A. A. (2024). Effects of Heuristic Problem-Solving strategies on students' achievement and retention in Mathematics in Ogun State, Nigeria. *Journal of Science and Mathematics Letters*, 12(1), 1–7. <https://doi.org/10.37134/jsml.vol12.1.1.2024>
- Al Mamun, M. A., & Lawrie, G. (2024). Cognitive presence in learner–content interaction process: The role of scaffolding in online self-regulated learning environments. *Journal of Computers in Education*, 11(3), 791–821. <https://doi.org/10.1007/s40692-023-00279-7>
- Andersen, R., Mørch, A. I., & Litherland, K. T. (2022). Collaborative learning with block-based programming: investigating human-centered artificial intelligence in education. *Behaviour and Information Technology*, 41(9), 1830–1847. <https://doi.org/10.1080/0144929X.2022.2083981>
- Anggraini, V. H. (2023). Mathematical Misconceptions of 7th Grade Students on Geometry Problem Using Three-tier Diagnostic Test. *AIP Conference Proceedings*, 2569. <https://doi.org/10.1063/5.0112357>
- Atman Uslu, N., Yildiz Durak, H., & Gökçe Mehmet, A. Y. (2022). Comparing reflective and supportive scaffolding in 3D computer-aided design course: Engineering students' metacognitive strategies, spatial ability self-efficacy, and spatial anxiety. *Computer Applications in Engineering Education*, 30(5), 1454–1469. <https://doi.org/10.1002/cae.22531>
- Ballon, E. M. M., Gomez, F. L. R., Castro, A. E. L. F., & Linares, M. R. F. C. (2024). Evaluating problem-solving and procedural skills offirst-year students in a Peruvian higher education institution. *Eurasia Journal of Mathematics, Science and Technology Education*, 20(2). <https://doi.org/10.29333/ejmste/14154>
- Barile, L. (2024). 'Effective strategies' for teaching mathematics in economics: testing prior knowledge, scaffolding and practical applications. *Teaching Mathematics and Its Applications*, 43(4), 430–448. <https://doi.org/10.1093/teamat/hrae022>
- Borthick, A. F., & Schneider, G. P. (2023). Getting Students Ready for Accounting Spreadsheets: Training for Basic Spreadsheet Skills with Pre/Post Assessments. *Issues in Accounting Education*, 38(2), 63–84. <https://doi.org/10.2308/ISSUES-2021-010>
- Cai, J., & Rott, B. (2024). On understanding mathematical problem-posing processes. *ZDM - Mathematics Education*, 56(1), 61–71. <https://doi.org/10.1007/s11858-023-01536-w>
- Chang, C. C., & Yang, S. T. (2023). Interactive effects of scaffolding digital game-based learning and cognitive style on adult learners' emotion, cognitive load and learning performance. *International Journal of Educational Technology in Higher Education*, 20(1). <https://doi.org/10.1186/s41239-023-00385-7>
- Chang, C. C., & Yang, S. T. (2024). Learners' positive and negative emotion, various cognitive processing, and cognitive effectiveness and efficiency in situated task-centered digital game-based learning with different scaffolds. *Interactive Learning Environments*, 32(9), 5058–5077. <https://doi.org/10.1080/10494820.2023.2209600>
- Chen, Y. C., Hou, H. T., & Wu, C. H. (2023). Design and Development of a Scaffolding-Based Mindtool for Gamified Learning Classrooms. *Journal of Educational Computing Research*, 61(1), 3–29. <https://doi.org/10.1177/07356331221101081>
- Choudhar, S., Bi, N., Singh, P. N., & Talwar, M. P. (2022). Study on Problem Solving Skills and Its Importance. *World Journal of English Language*, 12(3), 47. <https://doi.org/10.5430/wjel.v12n3p47>

- Deibl, I., Zumbach, J., & Fleischer, T. (2023). Visualization and metacognitive scaffolding in learning from animations. *Social Sciences & Humanities Open*, 8(1), 100601. <https://doi.org/https://doi.org/10.1016/j.ssaho.2023.100601>
- Dewi, N. R., Ardiansyah, A. S., & Amidi. (2023). Analysis of mathematical problem solving ability based on students' mathematical prior knowledge in ICT-assisted preprospec learning model. *International Conference on Mathematics, Science and Education, ICMSE 2021*, 040083. <https://doi.org/10.1063/5.0125830>
- Efuansyah, E., Lukito, A., & Wijayanti, P. (2024). Utilizing task with scaffolding: growth of students' mathematical understanding from layers of image having to property noticing. *Perspectives of Science and Education*, 70(4), 382–395. <https://doi.org/10.32744/pse.2024.4.24>
- Erman, E., Pare, B., Susiyawati, E., Martini, M., & Subekti, H. (2022). Using Scaffolding Set to Help Student Addressing Socio-Scientific Issues in Biochemistry Classes. *International Journal of Instruction*, 15(4), 871–888. <https://doi.org/10.29333/iji.2022.15447a>
- Fensie, A., Pierre, T. S., Jain, J., & Sezen-Barrie, A. (2024a). Engaged learning during distraction: a case study of successful working moms in distance education. *Journal of Computing in Higher Education*, 36(2), 389–434. <https://doi.org/10.1007/s12528-023-09359-0>
- Fensie, A., Pierre, T. S., Jain, J., & Sezen-Barrie, A. (2024b). Engaged learning during distraction: a case study of successful working moms in distance education. *Journal of Computing in Higher Education*, 36(2), 389–434. <https://doi.org/10.1007/s12528-023-09359-0>
- Fisher, D., Dahlan, J. A., & Putra, B. Y. G. (2022). MATHEMATICAL SELF-ESTEEM ABILITY OF JUNIOR HIGH SCHOOL STUDENTS IN PROJECT-BASED LEARNING. *Infinity Journal*, 11(2), 273–284. <https://doi.org/10.22460/infinity.v11i2.p273-284>
- Ghadiri, S., Tajeddin, Z., & Alemi, M. (2024). Teachers' Means of Scaffolding L2 Learners' Pragmatic Production in Online Instruction. *Iranian Journal of Language Teaching Research*, 12(2), 19–38. <https://doi.org/10.30466/ijltr.2024.54755.2550>
- Handayanto, S. K., Fawaiz, S., & Taufiq, A. (2024). USING E-SCAFFOLDING TO DEVELOP STUDENTS' SCIENTIFIC REASONING THROUGH INQUIRY-BASED LEARNING. *Obrazovanie i Nauka*, 26(3), 69–90. <https://doi.org/10.17853/1994-5639-2024-3082>
- Heitzmann, N., Stadler, M., Richters, C., Radkowitsch, A., Schmidmaier, R., Weidenbusch, M., & Fischer, M. R. (2023). Learners' adjustment strategies following impasses in simulations - Effects of prior knowledge. *Learning and Instruction*, 83, 101632. <https://doi.org/https://doi.org/10.1016/j.learninstruc.2022.101632>
- Hockham, D., & Wallis, J. (2024). Operationalising the concept of recontextualisation: leveraging pedagogy and learning strategies in higher education practical courses. *Higher Education*, 88(2), 645–660. <https://doi.org/10.1007/s10734-023-01136-3>
- Hwang, G. J., Chiu, M. C., Hsia, L. H., & Chu, H. C. (2023). Promoting art appreciation performances and behaviors in effective and joyful contexts: A two-tier test-based digital gaming approach. *Computers & Education*, 194, 104706. <https://doi.org/https://doi.org/10.1016/j.compedu.2022.104706>
- Jung, J., Shin, Y., Chung, H., & Fanguy, M. (2024). The effects of pre-training types on cognitive load, self-efficacy, and problem-solving in computer programming. *Journal of Computing in Higher Education*. <https://doi.org/10.1007/s12528-024-09407-3>

- Karla, D., Pandey, V. K., Rastogi, P., & Kumar, S. (2022). A Comprehensive Review on Significance of Problem-Solving Abilities in Workplace. *World Journal of English Language*, 12(3), 88. <https://doi.org/10.5430/wjel.v12n3p88>
- Kim, P. W. (2024). A Framework to Overcome the Dark Side of Generative Artificial Intelligence (GAI) Like ChatGPT in Social Media and Education. *IEEE Transactions on Computational Social Systems*, 11(4), 5266–5274. <https://doi.org/10.1109/TCSS.2023.3315237>
- Kusmaryono, I., & Kusumaningsih, W. (2021). Construction of students' mathematical knowledge in the zone of proximal development and zone of potential construction. *European Journal of Educational Research*, 10(1), 341–351. <https://doi.org/10.12973/eu-jer.10.1.341>
- Lamsombat, K., & Kanjug, I. (2021). A Study of Learner's Scientific Thinking Using Constructivist Virtual Learning Environment for Grade 11 Students. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 13117 LNCS, 95–101. https://doi.org/10.1007/978-3-030-91540-7_11
- Lataifeh, M., Carrasco, X. A., Elnagar, A. M., Ahmed, N., & Junejo, I. (2024). Human-machine co-creation: a complementary cognitive approach to creative character design process using GANs. *Journal of Supercomputing*, 80(11), 16574–16610. <https://doi.org/10.1007/s11227-024-06083-z>
- Lin, Y. C., Chien, S. Y., & Hou, H. T. (2024). A multi-dimensional scaffolding-based virtual reality educational board game design framework for service skills training. *Education and Information Technologies*. <https://doi.org/10.1007/s10639-024-13243-4>
- Machmud, M. T., Wattanachai, S., & Samat, C. (2023). Constructivist gamification environment model designing framework to improve ill-structured problem solving in learning sciences. *Educational Technology Research and Development*, 71(6), 2413–2429. <https://doi.org/10.1007/s11423-023-10279-0>
- Mahan, K. R. (2022). The comprehending teacher: scaffolding in content and language integrated learning (CLIL). *Language Learning Journal*, 50(1), 74–88. <https://doi.org/10.1080/09571736.2019.1705879>
- Manalo, E., & Fukuda, M. (2021). Diagrams in Essays: Exploring the Kinds of Diagrams Students Generate and How Well They Work. *12th International Conference on the Theory and Application of Diagrams, Diagrams 2021*, 553–561. https://doi.org/10.1007/978-3-030-86062-2_56
- Mustafa, S., Riana, R., Baharullah, B., & Maming, K. (2024). The Collaboration of Teaching at the Right Level Approach with Problem-Based Learning Model. *Open Education Studies*, 6(1). <https://doi.org/10.1515/edu-2024-0046>
- Nazerian, S., Abbasian, G. R., & Mohseni, A. (2021). Measurement and incorporation of ZPD scenarios in developing writing accuracy in EFL classes. *Cogent Education*, 8(1). <https://doi.org/10.1080/2331186X.2021.1968735>
- Nocera Alves Junior, P., Leger, P., & Costa Melo, I. (2024). Efficiency analysis of engineering classes: A DEA approach encompassing active learning and expositive classes towards quality education. *Environmental Science and Policy*, 160. <https://doi.org/10.1016/j.envsci.2024.103856>

- Nunthaitaweekul, P., Chaijaroen, S., & Gamlunglert, R. (2021). Development of Constructivist Web-Based Learning Environment Model to Enhance Critical Thinking: Integration Between Pedagogy and Neuroscience Topic on Substance for Primary Students. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 13117 LNCS, 219–227. https://doi.org/10.1007/978-3-030-91540-7_24
- OECD. (2024). *PISA 2022 Technical Report*. OECD Publishing. https://www.oecd-ilibrary.org/education/pisa-2022-technical-report_01820d6d-en
- Phuong, V. T. (2023). The effects of instructional scaffolding for writing skill of English majored students. *Perspektivy Nauki i Obrazovania*, 64(4), 158–169. <https://doi.org/10.32744/pse.2023.4.10>
- Puntambekar, S. (2022). Distributed Scaffolding: Scaffolding Students in Classroom Environments. *Educational Psychology Review*, 34(1), 451–472. <https://doi.org/10.1007/s10648-021-09636-3>
- Qin, L. (2022). The “wrong Love” between the Zone of Proximal Development and Scaffolding: An Interview with Prof. James P. Lantolf. *Chinese Journal of Applied Linguistics*, 45(1), 138–149. <https://doi.org/10.1515/CJAL-2022-0110>
- Rahmawati, Y., Afrizal, A., Astari, D. D., Mardiah, A., Utami, D. B., & Muhab, S. (2021). The integration of dilemmas stories with stem-project-based learning: Analyzing students’ thinking skills using hess’ cognitive rigor matrix. *Journal of Technology and Science Education*, 11(2), 419–439. <https://doi.org/10.3926/jotse.1292>
- Rohde Poole, S. B. (2024). Designing Mini Modeling Projects. *PRIMUS*, 34(9), 925–940. <https://doi.org/10.1080/10511970.2024.2387171>
- Sirimathep, K., Kanjug, I., Samat, C., & Wattanachai, S. (2022). The Design and Development of the Mobile Based Learning Environment to Enhance Computational Problem Solving in Programming for High School Students. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 13449 LNCS, 491–500. https://doi.org/10.1007/978-3-031-15273-3_54
- Song, Y., Roohr, K. C., & Kirova, D. (2024). Exploring approaches for developing and evaluating workplace critical thinking skills. *Thinking Skills and Creativity*, 51, 101460. <https://doi.org/10.1016/j.tsc.2023.101460>
- Thomas, G. L., Bailey, J., & Engeness, I. (2023). Scaffolding athlete learning in preparation for competition: what matters. *Sports Coaching Review*, 12(3), 281–301. <https://doi.org/10.1080/21640629.2021.1991713>
- Toplak, M. E., & Flora, D. B. (2021). Resistance to cognitive biases: Longitudinal trajectories and associations with cognitive abilities and academic achievement across development. *Journal of Behavioral Decision Making*, 34(3), 344–358. <https://doi.org/10.1002/bdm.2214>
- Valdez, F. A. O., & Taganap, E. C. (2024). Error Analysis of Pre-Service Mathematics Teachers in Solving Verbal Problems. *Mathematics Teaching-Research Journal*, 16(4), 6–34. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85209757088&partnerID=40&md5=e0eb1ade8037bd4730acd48c66bf5f2e>
- Wang, F., Huang, J., Zheng, X. L., Wu, J. Q., & Zhao, A. P. (2024). STEM activities for boosting pupils' computational thinking and reducing cognitive load: argumentation scaffolding and mental rotation roles. *Journal of Research on Technology in Education*. <https://doi.org/10.1080/15391523.2024.2398504>

- Wang, H. C., & Hsiao, C. H. (2022). EFFECTS OF ADVANCE ORGANIZERS ON TAIWANESE MIDDLE SCHOOL STUDENTS' ENGLISH-VIDEO LISTENING COMPREHENSION. *Taiwan Journal of TESOL*, 19(2), 107–144. [https://doi.org/10.30397/TJTESOL.202210_19\(2\).0004](https://doi.org/10.30397/TJTESOL.202210_19(2).0004)
- Wang, Q., Peng, Y., & Wang, H. (2022). A Curation Activity-Based Self-Regulated Learning Promotion Approach as Scaffolding to Improving Learners' Performance in STEM Courses. *Journal of Educational Computing Research*, 60(4), 843–876. <https://doi.org/10.1177/07356331211056532>
- Webb, N. M., Franke, M. L., Johnson, N. C., Ing, M., & Zimmerman, J. (2023). Learning through explaining and engaging with others' mathematical ideas. *Mathematical Thinking and Learning*, 25(4), 438–464. <https://doi.org/10.1080/10986065.2021.1990744>
- Wijayanti, A., & Yanto, A. (2023). Pembelajaran Matematika Menyenangkan di SD Melalui Permainan. *Polinomial : Jurnal Pendidikan Matematika*, 2(1), 18–23. <https://doi.org/10.56916/jp.v2i1.316>
- Wijayanti, K. (2023). Students' Mathematical Creative Thinking Obstacle and Scaffolding in Solving Derivative Problems. *Journal of Higher Education Theory and Practice*, 23(17), 150–169. <https://doi.org/10.33423/jhetp.v23i17.6540>
- Ye, L., Wang, R., & Zhao, J. (2021). Enhancing Learning Performance and Motivation of Cultural Heritage Using Serious Games. *Journal of Educational Computing Research*, 59(2), 287–317. <https://doi.org/10.1177/0735633120963828>
- Ye, Y., & Kaplan-Rakowski, R. (2024). An exploratory study on practising listening comprehension skills in high-immersion virtual reality. *British Journal of Educational Technology*, 55(4), 1651–1672. <https://doi.org/10.1111/bjet.13481>
- Yennita, Y. (2021). Problem-based learning (PBL) and blended learning in improving critical thinking skills and student learning activities in biochemistry courses. In *Journal of Physics: Conference Series* (Vol. 1731, Issue 1). <https://doi.org/10.1088/1742-6596/1731/1/012007>
- Zentgraf, K., & Prediger, S. (2024). Demands and scaffolds for explaining the connection of multiple representations: Revisiting the bottle-filling task. *The Journal of Mathematical Behavior*, 73, 101118. <https://doi.org/10.1016/j.jmathb.2023.101118>
- Zhang, C., & Jia, B. (2024). Enriching STEAM education with visual art: education benefits, teaching examples, and trends. *Discover Education*, 3(1). <https://doi.org/10.1007/s44217-024-00354-w>
- Zhu, C., Klapwijk, R., Silva-Ordaz, M., Spandaw, J., & de Vries, M. J. (2024). Investigating the role of spatial thinking in children's design ideation through an open-ended design-by-analogy challenge. *International Journal of Technology and Design Education*, 34(5), 1733–1762. <https://doi.org/10.1007/s10798-024-09877-7>

About the Contributor(s)

Dr. Aan Hendrayana, is an assistant professor at Universitas Sultan Ageng Tirtayasa, Department of Mathematics Education. His research interests include teaching children, scaffolding, cognitive load theory, multimedia, and technology information education. He has articles in national and international journals and has authored books published in the field of education.

Email: aanhendrayana@untirta.ac.id

ORCID: <http://orcid.org/0000-0002-7954-2077>

Dr. Anwar Mutaqin, is the Head of Research Centre for Educational, Vocational and Distance Learning Innovation – LPPM Untirta, an assistant professor at Universitas Sultan Ageng Tirtayasa , Department of Mathematics Education. His research focuses on mathematical proofs, emphasising the use of faded example strategies to reduce cognitive load among undergraduate students.

Email: anwar_mutaqin@untirta.ac.id

ORCID: <https://orcid.org/0000-0002-5783-2209>

Publisher's Note: *The opinions, statements, and data presented in all publications are solely those of the individual author(s) and contributors and do not reflect the views of Universitepark, EDUPIJ, and/or the editor(s). Universitepark, the Journal, and/or the editor(s) accept no responsibility for any harm or damage to persons or property arising from the use of ideas, methods, instructions, or products mentioned in the content.*
