



The Effect of Wordwall-Integrated Problem-Based Learning on Mathematical Problem-Solving: The Moderating Role of Mathematical Anxiety

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ABSTRACT

This study examines the impact of Problem-Based Learning integrated with the Wordwall edugame on students' mathematical problem-solving ability in trigonometry ratios based on their anxiety level. A quantitative quasi-experimental design was utilized with a pretest-posttest non-equivalent control group design involving 64 tenth-grade students in Jakarta. The experimental group underwent Problem-Based Learning integrated with Wordwall, while the control group received conventional treatment. Data were gathered through a mathematical problem-solving essay test grounded in Polya's indicators and an anxiety questionnaire. The findings revealed that the experimental group achieved a moderate N-Gain score in mathematical problem-solving ability ($M = 0.53$), whereas the control group demonstrated a lower gain ($M = 0.15$). Statistical analysis indicated a statistically significant difference between the two groups ($p < 0.001$). Nevertheless, no significant differences in mathematical problem-solving ability were observed across anxiety levels, and no significant interaction effect was found between treatment and anxiety level. These findings suggest that the mathematical anxiety level was not significantly associated with students' mathematical problem-solving ability in the present study. These results suggest that Problem-Based Learning integrated with the Wordwall edugame consistently and effectively enhances students' mathematical problem-solving ability across all anxiety levels.

Keywords: Anxiety, Mathematical problem-solving ability, Problem-based learning, Trigonometry ratios, Wordwall edugame

ABSTRAK

Penelitian ini bertujuan untuk mengkaji pengaruh Problem-Based Learning yang diintegrasikan dengan edugame Wordwall terhadap kemampuan pemecahan masalah matematis siswa pada materi perbandingan trigonometri berdasarkan tingkat kecemasan matematis mereka. Penelitian ini menggunakan pendekatan kuantitatif dengan desain kuasi-eksperimen berupa pretest-posttest non-equivalent control group design yang melibatkan 64 siswa kelas X di Jakarta. Kelompok eksperimen memperoleh pembelajaran *Problem-Based Learning* yang diintegrasikan dengan Wordwall, sedangkan kelompok kontrol memperoleh pembelajaran konvensional. Data dikumpulkan melalui tes esai kemampuan pemecahan masalah matematis yang disusun berdasarkan indikator Polya serta angket kecemasan matematis. Hasil penelitian menunjukkan bahwa kelompok eksperimen memperoleh skor N-Gain sedang pada kemampuan pemecahan masalah matematis ($M = 0,53$), sedangkan kelompok kontrol memperoleh peningkatan yang lebih rendah ($M = 0,15$). Analisis statistik menunjukkan adanya perbedaan yang signifikan antara kedua kelompok ($p < 0,001$). Namun demikian, tidak ditemukan perbedaan yang signifikan dalam kemampuan pemecahan masalah matematis berdasarkan tingkat kecemasan, serta tidak ditemukan efek



interaksi yang signifikan antara perlakuan dan tingkat kecemasan. Temuan ini menunjukkan bahwa tingkat kecemasan matematis tidak berhubungan secara signifikan dengan kemampuan pemecahan masalah matematis siswa dalam penelitian ini. Hasil penelitian ini menunjukkan bahwa *Problem-Based Learning* yang diintegrasikan dengan edugame Wordwall secara konsisten dan efektif meningkatkan kemampuan pemecahan masalah matematis siswa pada semua tingkat kecemasan.

Kata Kunci: kecemasan, kemampuan pemecahan masalah matematis, Problem-Based Learning, perbandingan trigonometri, edugame Wordwall

INTRODUCTION

The 21st century demands that our students develop a range of competencies, including higher-order thinking skills and technological literacy. One important aspect of higher-order thinking skills is problem-solving ability (Almerich et al., 2020). This skill is defined as an individual's capability to solve problems that cannot be addressed through routine procedures and to apply such capabilities in real-life situations (Kipman et al., 2022; Monica et al., 2019; Polya, 1975). In mathematics education, problem-solving ability is regarded as a key indicator of instructional effectiveness (NCTM, 2000; Widodo et al., 2025). It is also considered an essential skill that needs to be systematically developed to prepare students for the demands of contemporary society (Qori & Hidayati, 2022). Nonetheless, numerous studies indicate that students' mathematical problem-solving ability in Indonesia remains a concern. For example, Lidiana & Sukestiyarno (2023) reported that secondary school students in Cirebon experienced difficulties in understanding mathematical problems and determining effective solution strategies. Similarly, Fitriani (2020) found that only 15 of 34 students at a secondary school in Yogyakarta were able to solve even the simplest problem-solving task. These findings suggest that strengthening students' mathematical problem-solving ability requires instructional learning that actively engage students in interpreting problems, developing solution strategies, and evaluating their solutions.

To address students' difficulties in mathematical problem-solving, instructional that provide opportunities for students to engage with meaningful and contextual problems are needed. Problem-Based Learning is a student-centered instructional learning in which learning begins with authentic or contextual problems that require students to investigate, develop solution strategies, communicate their reasoning, and evaluate the solutions they obtain (Hmelo-Silver & DeSimone, 2013). These characteristics make Problem-Based Learning particularly relevant to the development of mathematical problem-solving ability (Tumangger et al., 2024; Wijayanti et al., 2022). Previous studies have reported that Problem-Based Learning can improve students' mathematical problem-solving performance (Lidiana & Sukestiyarno, 2023; Monica et al., 2019; Marchy et al., 2022). However, the effectiveness of Problem-Based Learning may be further strengthened when students are provided with interactive digital learning environments that encourage active participation and immediate engagement with learning tasks.

The integration of educational games into Problem-Based Learning may provide an opportunity to make problem-solving activities more interactive and engaging. One digital platform

that can be incorporated into mathematics instruction is Wordwall, a game-based learning platform that provides interactive activity formats, including quizzes, matching activities, and random-wheel tasks (Sari & Yarza, [2021](#)). Previous studies have shown that Wordwall can support several aspects of students' cognitive engagement in mathematics. Salsabila & Tsurayya ([2024](#)), for example, reported improvements in students' mathematical representation ability following the use of Wordwall, while Mudrika et al. ([2024](#)) found that Wordwall-based learning was associated with improvements in students' critical thinking skills. These findings suggest that Wordwall has potential as a complementary digital medium within Problem-Based Learning by providing interactive tasks that can support students' engagement with mathematical problems. Nevertheless, empirical evidence specifically examining the effect of Wordwall-integrated Problem-Based Learning on mathematical problem-solving remains limited.

Beyond cognitive outcomes, the use of digital educational games may also influence students' affective experiences during learning. Khairunnisa et al. ([2025](#)) demonstrated that Wordwall can improve students' learning motivation, while Oktavia et al. ([2025](#)) reported increased student engagement in Wordwall-based activities. These findings are important because students' affective characteristics may shape how they respond to problem-based mathematical learning. However, research examining the relationship between Wordwall-based learning and specific affective factors, particularly mathematical anxiety, remains limited. Mathematical anxiety refers to a negative emotional response that arises when individuals encounter mathematics-related tasks or situations and is often characterized by feelings of fear, nervousness, tension, or discomfort (Ganley et al., [2019](#); Lailiyah et al., [2021](#)). Mathematical anxiety is particularly relevant to the present study because it may interfere with students' concentration, retrieval of mathematical knowledge, and development of effective solution strategies during problem-solving (Ramirez et al., [2018](#); Zhu et al., [2024](#)). Previous studies have demonstrated that mathematical anxiety is negatively associated with students' mathematical performance, particularly in problem-solving tasks (Prasetyo & Dasari, [2023](#); Zhang et al., [2019](#)). Therefore, mathematical anxiety represents an important affective factor to consider when examining the effectiveness of instructional interventions designed to improve students' mathematical problem-solving ability.

To further examine the research landscape, a bibliometric analysis was conducted using Publish or Perish and VOSviewer on 551 publications retrieved using the keyword "mathematical problem-solving skills." The visualization indicates that the keyword "anxiety" has a relatively limited connection with "mathematical problem-solving" compared with other frequently occurring keywords (Figure 1). This pattern suggests that the relationship between mathematical problem-solving, anxiety, and technology-supported instructional learning remains insufficiently connected in the existing research literature.

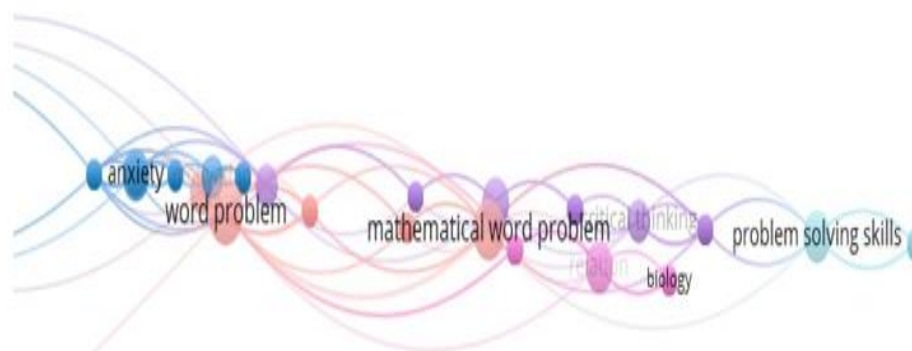


Figure 1. Bibliometric Mapping of Research on Mathematical Problem-Solving Skills

Although previous studies have examined Problem-Based Learning and Wordwall as instructional approaches for improving students' mathematical learning, several gaps remain. First, previous research has predominantly examined Problem-Based Learning or Wordwall separately, rather than investigating their integration within a problem-based learning environment. Second, although Wordwall has been reported to support students' cognitive and affective engagement, empirical evidence regarding its contribution to mathematical problem-solving remains limited. Third, and most importantly, relatively little is known about whether the effectiveness of Wordwall-integrated Problem-Based Learning varies according to students' levels of mathematical anxiety. Thus, examining the interaction between instructional treatment and mathematical anxiety may provide a more comprehensive understanding of when and for whom technology-supported Problem-Based Learning is most effective in developing mathematical problem-solving ability.

For example, Kusmaya & Prabawati (2022) reported that the use of Wordwall as an educational game was effective in improving middle school students' mathematical problem-solving ability in the context of integer operations. Similarly, Rahmatussolihah et al. (2024) found that Wordwall-based learning improved students' motivation to a high category at the junior high school level. While these findings provide initial evidence of the potential of Wordwall for supporting mathematical learning, they did not examine whether its effectiveness differs according to students' mathematical anxiety levels or whether Wordwall is particularly effective when integrated into a Problem-Based Learning framework.

Building on these gaps, the present study examines the effect of Wordwall-integrated Problem-Based Learning on students' mathematical problem-solving ability while considering mathematical anxiety as a potential moderating factor. Rather than examining the effect of Problem-Based Learning or Wordwall in isolation, this study focuses on whether integrating an interactive educational game into Problem-Based Learning can enhance mathematical problem-solving and whether its effectiveness differs across students with different levels of mathematical anxiety. Accordingly, the study addresses the following research questions:

RQ1: Does Problem-Based Learning, integrated with the Wordwall edugame, significantly improve students' mathematical problem-solving ability compared to conventional instruction?

RQ2: Are there significant differences in students' mathematical problem-solving ability across different levels of anxiety?

RQ3: Is there a significant interaction effect between Wordwall-integrated Problem-Based Learning and students' mathematical anxiety levels on their mathematical problem-solving ability?

METHOD

Research Design

This research employs a quantitative, quasi-experimental design with a pre-test and post-test, non-equivalent control group design. The independent variable was the use of Problem-Based Learning integrated with Wordwall edugame, operationally defined as a learning approach in which students engaged with contextual mathematical problems through structured worksheets designed based on Polya's four problem-solving stages: understanding the problem, devising a plan, carrying out the plan, and looking back (Polya, 1975). Wordwall was integrated at multiple stages of the learning process, specifically during problem orientation, group investigation, and formative evaluation, to support students' active engagement and reinforce their problem-solving practice. The control group was taught using conventional learning without Wordwall. The dependent variable was the students' mathematical problem-solving ability, measured through a written essay test based on Polya's four indicators.

To examine whether mathematical anxiety moderated the effectiveness of the instructional treatment, a 2×3 factorial framework was employed. The instructional treatment consisted of two levels: Wordwall-integrated Problem-Based Learning and conventional instruction, while mathematical anxiety consisted of three levels: low, moderate, and high. Mathematical anxiety was treated as the moderating variable and was measured using a Likert-scale questionnaire covering cognitive, physical, and behavioral dimensions of anxiety (Putri et al., 2020). Anxiety levels were determined from students' total questionnaire scores using the overall sample mean and standard deviation as cut-off points (Rayner et al., 2009). Students scoring more than one standard deviation above the mean were classified as having high anxiety, those scoring more than one standard deviation below the mean were classified as having low anxiety, and the remaining students were classified as having moderate anxiety.

The factorial framework was used to examine the main effect of instructional treatment, the main effect of mathematical anxiety, and, most importantly, the interaction between instructional treatment and mathematical anxiety on students' mathematical problem-solving ability. Because the study used intact classes rather than random assignment, students' pretest problem-solving scores were considered as an indicator of baseline ability when interpreting the treatment effect. The study was conducted at a public senior high school in West Jakarta over four instructional sessions during the even semester of the 2025/2026 academic year, covering trigonometric ratios in the Grade 10 mathematics curriculum.

Participants

The sample comprised two classes selected through purposive sampling based on teacher recommendations and school administration. The selected classes were taught by the same mathematics teacher, followed the same curriculum, and had mathematics lessons scheduled in the

morning to ensure consistency in instructional implementation and minimize potential variations due to different teaching practices or lesson schedules. The experimental group consisted of Class X-1, comprising 32 students, and the control group consisted of Class X-6, also comprising 32 students, bringing the total sample to 64.

The two selected classes were comparable in terms of curriculum, mathematics teacher, instructional schedule, and learning context. Both classes were taught by the same mathematics teacher and received the same mathematics content during the study period. The use of the same teacher and comparable instructional conditions was intended to reduce potential variation arising from differences in teaching style, curriculum coverage, and instructional time. Nevertheless, because intact classes were used and students were not randomly assigned to the experimental and control conditions, potential baseline differences in mathematical problem-solving ability were acknowledged and statistically considered in the subsequent analysis.

Before the intervention, both groups completed a mathematical problem-solving pretest and a mathematical anxiety questionnaire. Mathematical anxiety was measured using a Likert-scale questionnaire and was subsequently classified into low, moderate, and high anxiety levels based on students' total scores. The anxiety classification was used as a moderating factor to examine whether the effectiveness of the instructional treatment differed across students with different levels of mathematical anxiety. Both groups subsequently completed the posttest after the instructional intervention.

2.3 Procedure

The research process started with the preparation of instructional materials, problem-solving worksheets, Wordwall-based activities, assessment instruments, and a mathematical anxiety questionnaire, followed by securing permission from the participating school. The pretest and mathematical anxiety questionnaire were subsequently administered to both groups on 6 and 7 January 2026, respectively, before the instructional intervention.

In the experimental class, problem-solving worksheets were integrated with Wordwall-based interactive activities and implemented across four sessions, with each session consisting of four lesson hours, resulting in a total of 16 lesson hours. The intervention period was adjusted to the school schedule and the instructional time allocated for trigonometric ratios in the Grade 10 mathematics curriculum. The differences between the instructional treatments provided to the experimental and control groups are presented in Table 1.

Table 1. Research Procedure for the Experimental and Control Groups

No	Experimental Treatment	Control Treatment
1	The teacher brainstormed the students' contextual questions and showed how the topic applies in real life	The teacher stated the material and the learning objective
2	A contextual real-world problem is presented first. Students write an initial hypothesis before they are taught or search the Internet	The teacher explained the topic, the definition of sine, cosine, and tangent, directly from the textbook
3	Group of 4-5 with clear workflow and assigned roles. Assessment criteria shared transparently at the start	Students work in some groups. They did some tutor friend learning

No	Experimental Treatment	Control Treatment
4	Students measure or simulate data, discover the angle-side pattern themselves, and build their own mathematical model. Teacher guides with probing questions	The teacher demonstrates worked examples step by step. Students solve similar exercises from the textbook or worksheet. The teacher answers questions when raised
5	Each group presents findings. Peers respond and question. The teacher facilitates and introduces formal concepts (sin, cos, tan) based on what students discovered.	The teacher goes through the answers on the board. Corrects mistakes. Students listen and adjust their notes.
6	Mutual appreciation between students. Reflective questions: "What did you learn?" A formative quiz using Wordwall was tested by the students	The teacher summarises the lesson. Occasionally asks, "Any questions?" And students can indicate whether they have a question.
7	Summarises key points together, previews the next topic, assigns a short take-home task, and closes with motivation for the next meeting.	Teacher assigns homework from the textbook. States the next topic.

Student engaged in completing worksheet exercises that integrated with Wordwall activity and were given opportunities to present and discuss their solutions. Wordwall activities were deliberately integrated at key stages of the problem-solving process, specifically during problem orientation to activate students' initial understanding, during group investigation to support the exploration of solution strategies, and during formative evaluation to reinforce and verify students' problem-solving outcomes. In the control class, the same mathematics content was delivered through conventional teacher instruction without Wordwall or a problem-based learning method. The posttest was subsequently administered to both groups upon completion of the instructional period.

Instruments

Data were collected using two instruments. The first was a six-item non-routine written essay test designed to measure students' mathematical problem-solving ability on the topic of trigonometric ratios. Each problem-solving item was designed to elicit evidence of the four stages of mathematical problem solving proposed by Polya (1975): understanding the problem, devising a plan, carrying out the plan, and looking back. The scoring rubric assessed students' responses at each stage using a maximum score of three points per indicator (Setiawan et al., 2021). Thus, the rubric was designed to capture not only whether students obtained the correct final answer but also the quality of their mathematical reasoning and solution process. The test items were reviewed to ensure alignment between the mathematical content, the targeted problem-solving indicators, and the learning objectives of the trigonometric-ratio topic.

The second instrument was a structured mathematical anxiety questionnaire using a four-point Likert scale (1 = Strongly Disagree to 4 = Strongly Agree), adapted from Putri et al. (2020). The questionnaire covered three dimensions of mathematical anxiety: cognitive, physical, and behavioral. The questionnaire was administered before the instructional intervention to determine students' initial anxiety levels, which were subsequently classified as low, moderate, or high for the moderation analysis. Mathematical anxiety was measured before the instructional intervention and was treated as a baseline moderating variable. The classification into low, moderate, and high anxiety was performed using the overall sample mean and standard deviation as cut-off points. Students scoring

more than one standard deviation above the mean were classified as having high anxiety, those scoring more than one standard deviation below the mean were classified as having low anxiety, and the remaining students were classified as having moderate anxiety. This classification was determined before the posttest analysis to ensure that students' anxiety levels represented their affective condition prior to the intervention rather than a response to the treatment. The three anxiety categories were subsequently used to examine whether the effect of the instructional treatment differed across levels of mathematical anxiety.

The mathematical problem-solving test was administered as a pretest and posttest to both groups, whereas the mathematical anxiety questionnaire was administered before the instructional intervention to establish students' baseline anxiety levels.

Validity and Reliability

All instruments were assessed for validity, both content and construct. Content validity was examined by three mathematics education professionals, while construct validity was tested through students beyond X grade and using Pearson Product-Moment correlation. The r-count values ranged from 0.285 to 0.75 for the problem-solving ability instrument and 0.215 to 0.59 for the mathematical anxiety instrument, indicating that all items were valid ($r\text{-table} = 0.279$, $N = 50$). Reliability was evaluated using Cronbach's Alpha with a minimum acceptable coefficient of 0.60 for both instruments. For the mathematical problem-solving ability test, a coefficient of $\alpha = 0.85$ was obtained. For the anxiety questionnaire, a coefficient of $\alpha = 0.75$ was achieved. In line with broadly accepted measures, problem-solving ability assessment has strong reliability ($\alpha \geq 0.80$), while the questionnaire instrument has enough reliability ($0.67 < \alpha < 0.8$), confirming that both instruments reliably measure their intended constructs and are appropriate for use in this study (Hasanah & Aini, 2025).

Data Analysis

Data analysis proceeds in three stages. First, descriptive statistics were computed to summarize score distributions across both groups, including means, standard deviations, minimum and maximum values, and normalized gain (N-Gain) scores. The N-Gain score was calculated using the formula proposed by Hake (1998) as $N - Gain = \frac{(S_f - S_i)}{(100 - S_i)}$. Where S_f is a final score (posttest) and S_i is an initial score (pre-test). The N-Gain scores were subsequently interpreted based on the following criteria (Hake, 1998): The $N\text{-Gain} \geq 0.70$ reflects high improvement; a value between $0.30 \leq N\text{-Gain} < 0.70$ reflects moderate improvement; and $N\text{-Gain} < 0.30$ reflects low improvement. This measure was selected as the primary outcome variable because it accounts for differences in students' initial ability, which is particularly important in quasi-experimental designs where baseline equivalence between groups cannot be guaranteed.

Second, the assumptions of normality and homogeneity of variance were examined using the Shapiro–Wilk test and Levene's test, respectively. These tests were conducted to determine whether parametric or non-parametric statistical procedures were appropriate for hypothesis testing. Finally,

hypothesis testing was conducted according to the characteristics of the data. If the assumptions for parametric analysis were not satisfied, equivalent non-parametric tests were applied. Differences between pretest and posttest scores in the experimental group (RQ1) were analyzed using the Wilcoxon Signed-Rank test, while differences in N-Gain scores between the experimental and control groups were examined using the Mann–Whitney U test. Differences in mathematical problem-solving ability across mathematical anxiety levels (RQ2) were analyzed using the Kruskal–Wallis test. To examine the interaction effect between the learning method and mathematical anxiety on students' mathematical problem-solving ability (RQ3), a two-way ANOVA based on the Aligned Rank Transform (ART) procedure was performed using ARTool. All statistical analyses were conducted at a significance level of $\alpha = 0.05$.

RESULT AND DISCUSSION

Descriptive Statistics

The sample data from two classes totals 64 students; each class has 32 students. The descriptive statistics of students' mathematical problem-solving ability for both groups are presented in Table 2.

	Experimental (X-1)			Control (X-6)		
	Pretest	Posttest	N-Gain	Pretest	Posttest	N-Gain
Mean	9.88	57.94	0.53	20.69	32.94	0.15
SD	11.09	24.52	0.26	18.96	16.44	0.10
Min	0	16	0.07	0	10	0.03
Max	32	92	0.92	64	72	0.51
N-Gain Category	Moderate			Low		

The experimental class (X-1) obtained a pretest mean of 9.88 (standard deviation (SD) = 11.09) and a posttest mean of 57.94 (SD = 24.52), yielding a mean N-Gain score of 0.53 (SD = 0.26), which is regarded as moderate category. In contrast, the control class (X-6) obtained a pretest mean of 20.69 (SD = 18.96) and a posttest mean of 32.94 (SD = 16.44), with a mean N-Gain score of 0.15 (SD = 0.10), which falls in the low category. Although the experimental class began with a lower pretest mean than the control class, it demonstrated a substantially greater improvement after the treatment, suggesting that the use of Problem-Based Learning integrated with Wordwall positively contributed to students' mathematical problem-solving ability. Some studies also show that Problem-Based learning, when integrated with Wordwall edugame, can enhance students' problem-solving ability (Laviona & Amidi, 2024; Mudrika et al., 2024). The descriptive statistics for the distribution of anxiety are shown in Table 3.

Anxiety Level	Experimental Group (n)	Experimental Group (%)	Control Group (n)	Control Group (%)
High	6	18.75%	5	15.63%
Medium	23	71.88%	19	59.38%
Low	3	9.38%	8	25.00%
Total	32	100%	32	100%

Based on Table 3, the distribution of students by anxiety level in both groups. In the experimental group, the majority of students ($n = 23$, 71.88%) were classified as having medium mathematical anxiety, followed by high anxiety ($n = 6$, 18.75%), and low anxiety ($n = 3$, 9.38%). Similarly, in the control group, most students were classified as medium anxiety ($n = 19$ or 59.38%), followed by low anxiety ($n = 8$ or 25.00%), and high anxiety ($n = 5$ or 15.63%). Overall, both groups were predominantly composed of students with medium mathematical anxiety, suggesting that the two groups had a relatively comparable anxiety profile before the treatment. This classification served as a basis for further analysis of whether the level of anxiety moderates the influence of the treatment on students' problem-solving skills.

Prerequisite Tests

Before hypothesis testing, normality and homogeneity analyses were carried out on the pretest, posttest, and N-Gain scores of both groups. The Shapiro-Wilk normality test was used to assess normality, as it is considered more appropriate for small to moderate sample sizes (Ahadi et al., 2023). The findings revealed that the pretest data did not follow a normal distribution in either group. The findings are shown in Table 4.

Table 4. Normality Test Result

Variable	Group	Statistics	df	Sig.
Pretest	Experimental	0.813	32	<0.001
	Control	0.875	32	0.012
Posttest	Experimental	0.934	32	0.051
	Control	0.927	32	0.036
N-Gain	Experimental	0.945	32	0.105
	Control	0.902	32	0.037

Table 3 presents the results of the normality and homogeneity tests conducted as prerequisite analyses before hypothesis testing. The results indicated that the pretest data were not normally distributed in either group (experimental: $W = 0.813$, $p < 0.001$; control: $W = 0.875$, $p = 0.012$). For the posttest scores, the experimental group met the normality assumption ($W = 0.934$, $p = 0.051$), while the control group did not ($W = 0.927$, $p = 0.036$). Similarly, for N-Gain scores, the experimental group was normally distributed ($W = 0.945$, $p = 0.105$), whereas the control group was not ($W = 0.902$, $p = 0.037$). The homogeneity of variance is shown in Table 5.

Table 5. Homogeneity Test Result

Variable	Statistics	df1	df2	Significance
Pretest	5.781	1	62	0.019
Posttest	7.073	1	62	0.010
N-Gain	34.047	1	62	<0.001

Regarding homogeneity of variance, Levene's test indicated that homogeneity of variance was not met across all measures. Pretest ($F = 5.781$, $p = 0.019$), posttest ($F = 7.073$, $p = 0.010$), and N-Gain ($F = 34.047$, $p < 0.001$). Since the assumptions of normality and homogeneity were not fully met, non-parametric tests were used for subsequent hypothesis testing.

The Effect of Problem-Based Learning Integrated with Wordwall on Mathematical Problem-Solving Ability

RQ1. Does Problem-Based Learning, integrated with the Wordwall edugame, significantly improve students' mathematical problem-solving ability compared to conventional treatment?

The hypotheses corresponding to this research question are:

Ha1. There is a difference in the improvement of students' problem-solving ability before and after the use of the Problem-Based Learning method integrated with Wordwall edugame in the experimental group

The Wilcoxon Signed-Rank test was conducted to examine whether students' mathematical problem-solving ability changed significantly from pretest to posttest following the implementation of Problem-Based Learning integrated with the Wordwall edugame in the experimental group. The analysis revealed a statistically significant improvement in students' problem-solving ability, $Z = -4.938$, $p < 0.001$, with a very large effect size ($r = 0.873$). This result indicates that the observed improvement was not only statistically significant but also substantial in magnitude, suggesting a meaningful change in students' mathematical problem-solving performance following the intervention. The finding was further supported by the between-group comparison. The Mann-Whitney U test showed that the experimental group obtained significantly higher N-Gain scores than the control group ($U = 88.50$, $p < 0.001$). Taken together, these findings indicate that students who experienced Wordwall-integrated Problem-Based Learning demonstrated greater improvement in mathematical problem-solving ability than students who received conventional instruction. Thus, the advantage of the intervention was evident not only in the pretest-to-posttest change within the experimental group but also in the magnitude of improvement relative to the control condition.

These findings are consistent with previous research demonstrating the potential of Wordwall-supported mathematics instruction to enhance students' problem-solving performance. Kusmaya & Prabawati (2022) reported that the use of the Wordwall educational game within mathematics instruction was effective in improving students' mathematical problem-solving ability. More directly aligned with the present intervention, Laviona & Amidi (2024) found that Problem-Based Learning assisted by Wordwall was effective in developing students' mathematical problem-solving ability and that students in the experimental class performed better than those in the control class. More recent evidence provides broader support for this finding. Cai et al. (2025), through a three-level meta-analysis of 21 primary studies comprising 60 effect sizes, found that digital game-based learning had a positive overall effect on students' problem-solving ability ($g = 0.654$). Importantly, the effect was substantially larger when digital game-based learning was combined with relevant teaching strategies ($g = 1.246$) than when digital games were used alone ($g = 0.399$). This finding is particularly relevant to the present study because Wordwall was not implemented as a stand-alone game; rather, it was embedded within a Problem-Based Learning framework. The convergence between the present findings and Cai et al. (2025) meta-analytic evidence therefore suggests that the effectiveness of digital game-based learning may depend not only on the digital tool itself but also on how effectively it is integrated with an appropriate pedagogical strategy.

This interpretation is also supported by a recent systematic review of Problem-Based Learning in K–12 mathematics. Ayari et al. (2025) reviewed 40 studies and found that integrated Problem-Based Learning approaches—including digital-based and game-based interventions—were more prevalent than exclusive Problem-Based Learning approaches. Problem-solving skills were among the most frequently assessed student outcomes, indicating the strong relevance of integrated Problem-Based Learning designs for developing mathematical problem-solving competencies. Thus, the present study extends this emerging evidence by demonstrating the potential of combining Problem-Based Learning with a specific interactive digital platform, Wordwall, in the context of Grade 10 mathematics.

Several instructional characteristics may help explain this advantage. Problem-Based Learning places students in situations where they must interpret contextual problems, identify relevant information, formulate solution strategies, and evaluate the reasonableness of their solutions. When these processes are supported by Wordwall-based interactive activities, students are provided with an additional digital environment for practicing concepts, responding to questions, and receiving immediate feedback. Rather than functioning merely as an entertainment component, Wordwall may therefore serve as a form of interactive reinforcement within a broader problem-solving learning sequence. This interpretation is consistent with a systematic review by Hui & Mahmud (2023) and Zeng et al. (2024), which found that game-based learning in mathematics was associated with positive outcomes across cognitive domains, including mathematical skills, as well as affective domains such as motivation, interest, and engagement. More recent reviews likewise indicate that digital game-based learning has continued to attract empirical attention in mathematics education, particularly because of its potential to support cognitive outcomes and positive learning attitudes (Yulianto et al., 2025).

The present findings also suggest that the added value of Wordwall may lie not in the digital game itself, but in its integration with a structured problem-solving pedagogy. The intervention required students to work through mathematical problems systematically, while Wordwall provided opportunities for interactive practice and reinforcement. This distinction is important because the present study does not provide evidence that Wordwall alone caused the observed improvement. Instead, the results support the effectiveness of the integrated instructional approach, in which Problem-Based Learning provided the cognitive and pedagogical structure and Wordwall functioned as a digital support for student interaction and practice. Such an interpretation is also consistent with Laviona & Amidi (2024), whose study specifically examined Wordwall-assisted Problem-Based Learning rather than Wordwall as an isolated instructional treatment. Beside that this interpretation is consistent with Cai et al. (2025) meta-analysis, which found that combining digital game-based learning with relevant teaching strategies produced substantially larger effects on problem-solving ability than using digital games alone.

Nevertheless, the mechanism underlying the observed improvement should be interpreted cautiously. The present study did not directly measure students' engagement, motivation, feedback experiences, or cognitive processes during the intervention. Therefore, these factors should be regarded as plausible explanatory mechanisms rather than empirically established mediators.

Further research could investigate whether engagement, motivation, immediate feedback, or students' perceived confidence mediate the effect of Wordwall-integrated Problem-Based Learning on mathematical problem-solving ability. Such research would help clarify why and for whom the integration of interactive digital games with problem-based instruction produces stronger learning gains.

Differences in Problem-Solving Ability Across Anxiety Levels (RQ2)

RQ2. Are there significant differences in students' mathematical problem-solving ability across different levels of anxiety?

The hypotheses corresponding to this research question are:

Ha1. There is a significant difference in students' mathematical problem-solving ability across different levels of mathematical anxiety: high, medium, and low.

The Kruskal–Wallis test was applied to examine whether students' improvement in mathematical problem-solving ability differed significantly across the three levels of mathematical anxiety. The analysis was conducted using the N-Gain scores of students in the experimental group. The results indicated no statistically significant difference in problem-solving improvement across the low-, moderate-, and high-anxiety groups, $H(2) = 0.633$, $p = 0.729$. Therefore, the null hypothesis was retained. This finding indicates that students with different levels of initial mathematical anxiety did not demonstrate statistically different levels of improvement in mathematical problem-solving ability following the Wordwall-integrated Problem-Based Learning intervention. Importantly, this result should not be interpreted as evidence that mathematical anxiety is unrelated to mathematical performance in general. Rather, it suggests that, within the instructional context examined in this study, initial differences in anxiety did not significantly differentiate students' learning gains.

This finding appears to differ from previous research reporting a negative relationship between mathematical anxiety and mathematics-related performance. Rohmah & Mashuri (2021) found that students with lower levels of mathematical anxiety tended to demonstrate better mathematical critical-thinking ability, while Umbara et al. (2024) reported that students with lower anxiety were able to solve problems and follow the stages of Polya's problem-solving process more effectively. More recent evidence also supports the general association between mathematical anxiety and mathematical performance. A meta-analysis of 31 experimental studies involving 106,636 students reported a moderate negative association between mathematics anxiety and mathematics achievement ($r = -0.322$), indicating that higher anxiety tends to be associated with poorer mathematical performance (Yan, 2024). Similarly, Putri & Meiliasari (2025) reported that mathematical anxiety may interfere with students' conceptual understanding, reasoning, and mathematical problem-solving processes. A recent systematic review of research on secondary-school students identified mathematical anxiety as a prominent issue in mathematics education and highlighted the need for further research into its relationship with students' mathematical experiences and performance (Iuit & Sosa, 2025).

The apparent difference between these findings and the present result may be related to differences in the research focus, instructional context, and outcome examined. Previous studies

primarily examined the relationship between mathematical anxiety and mathematical performance, critical thinking, or students' ability to carry out problem-solving processes. In contrast, the present study specifically examined whether students' improvement in problem-solving ability following a particular instructional intervention differed according to their initial anxiety level. Thus, a negative relationship between anxiety and mathematics performance does not necessarily imply that students with different anxiety levels will experience significantly different learning gains when exposed to the same instructional intervention. The present finding therefore provides a more contextualized perspective on the role of mathematical anxiety in technology-supported problem-based mathematics learning.

One possible explanation concerns the instructional characteristics of the Wordwall-integrated Problem-Based Learning intervention. The intervention combined contextual problem solving, structured problem-solving stages, collaborative learning, and interactive digital activities. These features may have provided students with repeated opportunities to engage with mathematical problems, receive feedback, and practice problem solving in a relatively low-stakes learning environment. Such characteristics may have reduced the extent to which differences in initial anxiety translated into differences in learning improvement. Recent work on anxiety-sensitive digital mathematics learning similarly highlights feedback, safe error handling, collaborative learning, and mastery-oriented practice as potentially supportive features for students experiencing mathematical anxiety. However, this explanation remains tentative because the present study did not directly measure changes in students' mathematical anxiety, classroom engagement, perceived competence, or their experiences with the Wordwall activities.

Moreover, the absence of a significant difference across anxiety levels should not be interpreted as evidence that Wordwall-integrated learning necessarily reduces mathematical anxiety. A meta-analysis of game-based interventions found only a small and relatively weak effect on reducing mathematics anxiety, with digital games showing particularly limited effects (Dondio et al., 2023). Therefore, the present finding is more appropriately interpreted as evidence that students' initial anxiety levels did not significantly differentiate their problem-solving gains within the intervention, rather than as evidence that the intervention eliminated or reduced the influence of mathematical anxiety. Future studies should directly examine whether changes in anxiety, learning engagement, self-efficacy, and perceived learning support explain why students with different initial anxiety levels may achieve comparable learning gains.

Interaction Effect Between Problem-Based Learning Integrated with Wordwall and Anxiety Level

RQ3: Is there a significant interaction effect between the use of Problem-Based Learning Integrated with Wordwall and students' anxiety level on their mathematical problem-solving ability?

The hypotheses corresponding to this research question are:

Ha. There is a significant interaction effect between the use of the Problem-Based Learning Integrated with Wordwall edugame and students' mathematical anxiety level on their mathematical problem-solving ability

The two-way analysis of variance using the Aligned Rank Transform (ART) procedure implemented in ARTool was conducted to determine whether the effect of instructional treatment on students' mathematical problem-solving improvement differed according to their level of mathematical anxiety. The analysis revealed a significant main effect of instructional treatment, $F_{(1, 58)} = 39.498$, $p < 0.001$, indicating that the N-Gain scores differed significantly between students receiving Problem-Based Learning integrated with Wordwall and those receiving conventional instruction. This result provides further evidence that the instructional intervention was associated with substantially greater improvement in mathematical problem-solving ability than conventional instruction. The effect remained statistically evident after mathematical anxiety and the treatment-by-anxiety interaction were incorporated into the factorial model, suggesting that the observed instructional advantage was not statistically contingent upon students' anxiety level.

In contrast, the main effect of mathematical anxiety was not statistically significant, $F_{(2, 58)} = 0.388$, $p = 0.680$. More importantly, the interaction between instructional treatment and mathematical anxiety was also not statistically significant, $F_{(2, 58)} = 0.253$, $p = 0.777$. The non-significant interaction indicates that there was insufficient statistical evidence to conclude that the effectiveness of Problem-Based Learning integrated with Wordwall varied across low-, moderate-, and high-anxiety students. In other words, the difference in learning gains between the experimental and control conditions did not significantly depend on students' initial anxiety category. This finding is important because it suggests that mathematical anxiety did not emerge as a statistically significant moderator of the treatment effect in the present sample. However, the result should not be interpreted as evidence that mathematical anxiety is irrelevant to mathematical learning or that the intervention eliminates the effects of anxiety. Rather, it indicates that the relative advantage of the intervention was statistically comparable across the three anxiety categories within the conditions and sample examined.

This interpretation is particularly important in light of recent evidence showing that improvements in academic outcomes do not necessarily coincide with changes in students' anxiety. A meta-analysis of 19 studies involving 2,377 secondary students found that academic interventions produced a significant positive effect on academic outcomes ($g = 0.66$), whereas their effect on academic anxiety was not statistically significant ($g = -0.13$). The authors therefore suggested that academic anxiety may require more direct intervention rather than being expected to change simply as a consequence of academic instruction (Fishstrom et al., 2025). This finding provides a useful context for the present study: students' mathematical problem-solving ability may improve substantially through an instructional intervention even when initial anxiety does not significantly alter the magnitude of that improvement. Thus, the absence of a significant treatment-by-anxiety interaction should not be viewed as contradictory to the established relevance of mathematical anxiety in mathematics learning.

The magnitude of the model effect further supports the substantive importance of the instructional treatment. The model explained approximately 50.2% of the variance in N-Gain scores ($R^2 = 0.502$), indicating that the factors included in the model accounted for a substantial proportion of the observed variation in students' learning gains. Nevertheless, the proportion of explained

variance should not be attributed exclusively to the Wordwall-integrated Problem-Based Learning treatment because the model also included mathematical anxiety and the treatment-by-anxiety interaction. Therefore, the R^2 value should be interpreted as the explanatory contribution of the factorial model as a whole rather than as the effect size of the intervention alone.

The absence of a significant interaction is consistent with the findings of Humaira & Miatun (2023), who examined the interaction between Problem-Based Learning and mathematical anxiety in relation to students' mathematical communication ability. Their study found a significant effect of Problem-Based Learning on mathematical communication ability but no significant interaction between Problem-Based Learning and mathematical anxiety. Although their outcome variable differed from the present study, the similarity in the interaction finding suggests that the effectiveness of Problem-Based Learning may not necessarily vary systematically according to students' mathematical anxiety. More recent evidence also provides a complementary perspective. Pramesti & Salsabila (2025) reported that Problem-Based Learning significantly improved mathematics learning outcomes when students' mathematical anxiety was taken into account. Because their analysis treated anxiety as a covariate rather than directly testing a treatment-by-anxiety interaction, their findings cannot be interpreted as direct evidence against moderation. Nevertheless, they provide converging evidence that project-based learning can remain beneficial in the presence of mathematical anxiety. The present study extends this evidence by directly examining whether the magnitude of the instructional advantage differs across anxiety levels, rather than merely statistically controlling for anxiety.

Recent research further suggests that the relationship between instructional design and mathematical anxiety is complex and context-dependent. A systematic literature review of 56 empirical studies identified instructional practices, teacher support, classroom climate, learning-task structure, and classroom routines as important factors associated with mathematics anxiety. The review also reported that strategies such as gamification and cognitive activation may be associated with lower levels of mathematics anxiety (Li et al., 2025). Similarly, Ma (2025), in a PRISMA-guided review of 35 sources, highlighted the potential role of instructional approaches and curriculum design in supporting students' engagement and confidence and in addressing mathematics anxiety. However, the effects of instructional approaches on anxiety are not uniform, suggesting that changes in anxiety should be examined directly rather than inferred from improvements in mathematical performance.

One plausible explanation for the absence of a significant interaction is that the pedagogical structure of Problem-Based Learning may have provided a common learning pathway for students regardless of their initial anxiety level. The intervention required students to engage with contextual problems, identify relevant information, formulate solution strategies, carry out mathematical procedures, and evaluate their solutions. The integration of Wordwall added an interactive component for practice and reinforcement within this structured problem-solving sequence. Consequently, the intervention may have provided multiple opportunities for students with different anxiety profiles to participate in the same learning process and develop problem-solving skills.

This interpretation is supported by recent evidence on gamification in mathematics education. A systematic review and meta-analysis published in 2026 found a small-to-moderate positive effect of gamification on students' mathematics motivation ($g = 0.383$), although the evidence for engagement was less conclusive because validated engagement measures were insufficiently available. The review further emphasized the importance of instructional design, recommending mastery-oriented and cooperative elements rather than excessive competition (Ratinho et al., 2026). These findings are relevant to the present intervention because Wordwall was not used merely as an isolated game; rather, it was embedded within a problem-based instructional sequence. Therefore, the potential contribution of Wordwall should be understood in relation to how the digital game was pedagogically integrated, rather than attributed to gamification alone.

Recent meta-analytic evidence on digital game-based learning also reinforces the importance of instructional and contextual conditions. Kusumawardani & Widhanarto (2026) found that Digital Game-Based Learning had a significant positive effect on mathematics achievement and reported that several characteristics—including intervention duration, game type, and level of curriculum integration—moderated its effectiveness. Importantly, the authors concluded that digital games tend to be most effective when embedded within regular instruction rather than used merely as supplementary activities. This finding provides a strong conceptual basis for interpreting the present results: the potential effectiveness of Wordwall may derive not simply from its game-like characteristics but from its integration into a structured Problem-Based Learning environment.

Importantly, the present finding also helps refine the interpretation of mathematical anxiety in instructional research. Previous studies have established that mathematical anxiety can be associated with poorer mathematics performance, but this does not necessarily mean that anxiety will moderate the effectiveness of every instructional intervention. The relationship may depend on the specific outcome, instructional design, duration of exposure, severity and distribution of anxiety, and characteristics of the learning environment. The current results therefore suggest that mathematical anxiety may be an important affective characteristic without necessarily functioning as a significant moderator of treatment effectiveness in every learning context. This distinction is theoretically important because it separates the question of whether anxiety is related to mathematical performance from the more specific question of whether anxiety changes the relative effectiveness of an instructional treatment. The present study addresses the second question and found no statistically significant moderation effect.

Nevertheless, the non-significant interaction should be interpreted in light of the study's methodological constraints. The sample consisted of only 64 students from two intact classes, the intervention lasted four sessions, and participants were selected purposively rather than randomly. In addition, categorizing mathematical anxiety into three levels may have reduced information contained in the original continuous scores and consequently limited the statistical power to detect subtle moderation effects. This issue is particularly important because recent evidence indicates that the effectiveness of digital game-based learning can vary according to contextual factors such as intervention duration and level of instructional integration (Kusumawardani & Widhanarto, 2026). Therefore, the absence of a significant interaction may reflect a genuinely stable treatment effect

across anxiety levels, but it may also be influenced by the relatively small sample, short intervention period, or categorical operationalization of anxiety. Future studies should replicate the research using larger and more diverse samples, longer intervention periods, and preferably continuous measures of mathematical anxiety. Such designs would provide greater statistical power to determine whether mathematical anxiety truly remains a non-significant moderator or whether more nuanced moderation effects emerge under different instructional conditions.

CONCLUSION

This study investigated the effectiveness of Problem-Based Learning integrated with the Wordwall edugame on students' mathematical problem-solving ability, the role of mathematical anxiety, and the interaction between the learning method and mathematical anxiety. First, the findings indicate that Problem-Based Learning integrated with the Wordwall edugame was more effective than conventional instruction in improving students' mathematical problem-solving ability. Second, no significant differences in mathematical problem-solving ability were found among students with different levels of mathematical anxiety. Third, no significant interaction was found between the learning method and mathematical anxiety, suggesting that the effectiveness of the intervention was consistent across students with different levels of mathematical anxiety.

Despite these findings, this study has several limitations. The relatively small sample size, the use of purposive sampling, and the short intervention period may limit the generalizability of the findings. Therefore, future research is recommended to involve larger and more diverse samples, apply longer intervention periods, and examine the effectiveness of Problem-Based Learning integrated with Wordwall in different mathematical topics and educational contexts.

DECLARATION OF THE USE OF AI

Statement: During the preparation of this work, the authors used Google Translate and Grammarly in order to check grammar, vocabulary, and spelling. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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