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Comparison of Problem-Based Learning and Game-Based Learning in Geometry Based on Grade 2 Students' Learning Motivation

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Abstract

Abstract

Geometry achievement in second-grade elementary school students remains relatively low because classroom instruction is often teacher-centered and provides limited opportunities for active student engagement. This study aimed to examine the effects of *Problem-Based Learning* (PBL) and *game-based learning* on geometry achievement in relation to students' learning motivation. A 2×2 quasi-experimental factorial design was employed involving 56 second-grade students from two classes. One class received PBL instruction, while the other participated in educational board game-based learning using a snakes-and-ladders game. Data were collected through a geometry achievement test and a learning motivation questionnaire that met validity and reliability requirements. Data were analyzed using two-way ANOVA after normality and homogeneity assumptions were satisfied. The results revealed significant effects of learning model on geometry achievement ($F = 36.13$, $p < .001$), learning motivation ($F = 10.26$, $p = .002$), and their interaction ($F = 14.13$, $p < .001$). Students in the PBL group achieved higher learning outcomes than those in the game-based learning group. This study contributes empirical evidence regarding the comparative effectiveness of PBL and board game-based learning for lower-grade elementary geometry instruction while considering learning motivation as a moderating variable.

Abstrak

Hasil belajar geometri pada materi bangun ruang siswa kelas II sekolah dasar masih relatif rendah karena pembelajaran cenderung berpusat pada guru dan kurang melibatkan siswa secara aktif. Penelitian ini bertujuan menganalisis pengaruh *Problem-Based Learning* (PBL) dan *game-based learning* terhadap hasil belajar geometri ditinjau dari motivasi belajar siswa sekolah dasar. Penelitian menggunakan desain *quasi-experimental* faktorial 2×2 yang melibatkan 56 siswa kelas II dari dua kelas. Satu kelas memperoleh pembelajaran PBL, sedangkan kelas lainnya memperoleh pembelajaran berbasis permainan ular tangga edukatif. Data dikumpulkan melalui tes hasil belajar geometri dan angket motivasi belajar yang telah memenuhi kriteria validitas dan reliabilitas. Analisis data dilakukan menggunakan ANOVA dua arah setelah memenuhi asumsi normalitas dan homogenitas. Hasil penelitian menunjukkan bahwa model pembelajaran berpengaruh signifikan terhadap hasil belajar geometri ($F = 36,13$; $p < 0,001$). Motivasi belajar juga berpengaruh signifikan terhadap hasil belajar ($F = 10,26$; $p = 0,002$). Selain itu, terdapat interaksi signifikan antara

model pembelajaran dan motivasi belajar (F = 14,13; p < 0,001). PBL menghasilkan capaian belajar yang lebih tinggi dibandingkan *game-based learning*. Penelitian ini memberikan bukti empiris mengenai efektivitas relatif PBL dan pembelajaran berbasis permainan pada pembelajaran geometri siswa kelas rendah sekolah dasar dengan mempertimbangkan motivasi belajar sebagai variabel moderator.

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1. INTRODUCTION

Mathematics learning at the elementary school level plays an important role in developing students' logical, systematic, critical, creative, and problem-solving skills from an early age. Mathematics not only serves as a means of mastering numerical concepts but also as a foundation for developing higher-order thinking skills required to face the challenges of the twenty-first century (Anazifa & Djukri, 2017; OECD, 2024). However, the abstract nature of mathematical concepts often presents challenges for young learners, particularly in geometry learning.

Among various mathematics topics, geometry—especially three-dimensional shapes—remains difficult for elementary school students. Learning geometric solids requires well-developed spatial reasoning and visualization abilities because students must understand the relationships between two-dimensional and three-dimensional representations (Bernabeu et al., 2024; Downton & Livy, 2022; Nazaruk, 2019; Pellegrino & Hilton, 2012) This challenge is particularly evident among lower-grade elementary school students who, according to Piaget's theory of cognitive development, are still in the concrete operational stage (Piaget & Barbel, 2000). At this stage, students learn more effectively through concrete experiences, visual representations, and manipulative activities. Nevertheless, classroom instruction often presents geometric concepts in abstract ways that are not aligned with students' developmental characteristics. Consequently, students frequently experience difficulties in understanding dimensions, spatial relationships, and geometric properties (Boonstra et al., 2023; Sharma, 2024).

The difficulties encountered in geometry learning are further exacerbated by instructional practices that remain predominantly teacher-centered. In many elementary classrooms, mathematics instruction still relies heavily on lectures, drills, and procedural memorization, limiting students' opportunities to actively construct mathematical understanding (Wang et al., 2018). Such traditional approaches often result in passive learning behaviors, low learner engagement, and negative attitudes toward mathematics, which may subsequently lead to mathematics anxiety and poor academic achievement (White & McCoy, 2019). These conditions indicate the need for instructional approaches that actively engage students in meaningful learning experiences and support conceptual understanding.

In response to these challenges, the educational paradigm of the twenty-first century emphasizes the importance of student-centered learning environments that promote critical thinking, problem solving, collaboration, creativity, and learner engagement (Anazifa & Djukri, 2017). Active learning strategies are therefore considered essential for improving mathematics learning outcomes, particularly in elementary education where meaningful experiences and active participation play a central role in knowledge construction.

One instructional approach that has received considerable attention is Problem-Based Learning (PBL). PBL positions students as active participants in the learning process by engaging them in authentic and contextual problems that require investigation, discussion, and solution development (Bang et al., 2023). Through these activities, students are encouraged to construct knowledge independently,

develop problem-solving skills, and achieve deeper conceptual understanding. Previous studies have reported that PBL significantly improves mathematics achievement, critical thinking skills, and problem-solving abilities among elementary school students (Ahmad et al., 2023; Wayan et al., 2024; Yew & Goh, 2016). Moreover, PBL has been shown to enhance students' behavioral and emotional engagement through collaborative and meaningful learning experiences (Anugraheni et al., 2026).

Another promising approach is game-based learning, which has gained increasing attention as an innovative instructional strategy for primary education (Bang et al., 2023; Plass & Pawar, 2020). By integrating educational game elements into classroom instruction, game-based learning creates interactive and enjoyable learning environments that increase students' attention and reduce mathematics anxiety (Plass & Pawar, 2020; Wang et al., 2018). In elementary mathematics learning, educational board games such as snakes and ladders are particularly relevant because they correspond with children's natural preference for playful activities. Through exploration, object manipulation, competition, and social interaction, game-based learning helps students understand abstract geometric concepts more concretely (Qian & Clark, 2016). Empirical evidence also indicates that integrating game elements into learning can improve students' motivation, participation, and mathematics achievement compared with traditional instructional approaches (Boom-Cárcamo et al., 2024; Brezovszky et al., 2019).

Beyond instructional approaches, learner characteristics also play a critical role in determining learning success. According to instructional design theory, effective learning outcomes result from the interaction between instructional strategies and learner characteristics (Degeng & Degeng, 2018). One of the most influential learner characteristics is learning motivation. Self-Determination Theory explains that intrinsic motivation significantly influences students' attention, engagement, participation, and persistence during learning activities (Ryan & Deci, 2020; Schunk et al., 2014). Students with higher learning motivation tend to demonstrate stronger efforts to construct conceptual understanding and achieve better academic performance. Previous empirical findings have consistently shown that motivation and engagement are strongly associated with mathematics achievement among elementary school students.

Although numerous studies have independently demonstrated the effectiveness of Problem-Based Learning and game-based learning in improving mathematics achievement, evidence directly comparing these two approaches within the same experimental context remains limited. Furthermore, PBL primarily emphasizes cognitive engagement and problem-solving processes, whereas game-based learning tends to promote motivation, enjoyment, and affective engagement. Consequently, the relative effectiveness of these approaches for teaching geometry, particularly three-dimensional shapes to lower-grade elementary school students, remains inconclusive. In addition, empirical studies examining the interaction between learning models and students' learning motivation in geometry learning are still scarce. This limitation leaves insufficient evidence regarding which instructional approach is more effective for students with different motivational characteristics.

To address this research gap, the present study aims to examine the effects of Problem-Based Learning and game-based learning on geometry learning outcomes among second-grade elementary school students, with learning motivation considered as a moderating variable. The findings are expected to contribute both theoretically and empirically to the development of learner-centered mathematics instruction that enhances student engagement, learning motivation, and academic achievement in elementary education.

2. METHODS

Research Design

This study is a quasi-experimental factorial 2×2 design (Creswell & Creswell, 2018). The research design was used to analyze the influence of learning models and learning motivation on the mathematics learning outcomes of elementary school students. The independent variables consisted of problem-based learning and game-based learning based on educational board games, while the moderator variable was learning motivation. Problem-Based Learning results in higher learning outcomes than game-based learning. The dependent variable was students' geometry learning outcomes. The 2x2 factorial design is described in Figure 1 below:

		Learning Strategy	
		Problem-Based Learning	Game-Based Learning (educational board game)
Students' Learning Motivation	High	19	2
	Low	9	26

Figure 1. Factorial design 2 x 2

Participants

The research subject consists of 2 classes, where there are 28 students each, so that the total research subject is 56 students. Quasi-experimental research assigned two classes into two learning groups, namely the problem-based learning group and the educational board game-based learning group. Figure 1 shows the division of students by class and student characteristics.

Instruments

The research instrument consisted of a mathematics learning outcome test and a learning motivation questionnaire. The validity of the instrument was tested using product-moment correlation, while the reliability of the instrument was analyzed using Cronbach's alpha. The test results showed that the instrument met the validity criteria and had a reliability of 0.759 so that it was suitable for use in the study. Identification of the number of students according to the level of learning motivation can be seen in Figure 1.

Data Analysis

Data analysis was carried out using two-way ANOVA to test the influence of learning models, learning motivation, and interaction of the two on students' mathematics learning outcomes. Before hypothesis testing was carried out, the data were tested using the Kolmogorov–Smirnov normality test and the Levene's test homogeneity test (Field, 2018).

3. RESULTS

3.1. Descriptive Statistic

The results of the descriptive analysis can be seen in Figure 2 as follow:

Descriptive Statistics

Dependent Variable: Learning outcome

Method	Learning Motivation	Mean	Std. Deviation	N
PBL	High	66.42	4.325	19
	Low	77.00	5.679	9
	Total	69.82	6.880	28
Snakes-and-Ladders Game	High	63.00	2.828	2
	Low	62.15	1.804	26
	Total	62.21	1.833	28
Total	High	66.10	4.277	21
	Low	65.97	7.302	35
	Total	66.02	6.294	56

Resource: SPPS

Figure 2. Descriptive Statistics learner outcome

Figure 2 indicated the average geometric learning outcomes of students in the problem-based learning group were higher than those in the game-based learning group. The problem-based learning group obtained an average learning outcome of 69.82, while the game-based learning group obtained an average of 62.21. Based on learning motivation, the average score of students who have high motivation is 66.10 and the group of students with low motivation scores of 65.97.

3.2 Two-Way ANOVA Result

Before testing the hypothesis, a prerequisite test was carried out in the form of normality and homogeneity tests. The results of the normality test using Kolmogorov–Smirnov showed a significance value of 0.200 (>0.05), so the data was declared to be normally distributed. Furthermore, the results of the homogeneity test showed that the entire significance value was above 0.05 so that the data met the homogeneity of variance assumption (see Figure 3).

Test of Homogeneity of Variances

		Levene Statistic	df1	df2	Sig.
Learning outcome	Base on Mean	1.460	1	54	.232
	Base on Median	1.389	1	54	.244
	Base on Median and with adjusted df	1.389	1	51.105	.244
	Base on trimmed mean	1.472	1	54	.230

Resource: SPPS

Figure 3. Result of Homogeneity Test

The results of the Normality test in Figure 4 are as follows:

One-Sample Kolmogorov-Smirnov Test

			Unstandardized Residual
N			56
Normal Parameters[a,b]	Mean		.0000000
	Std. Deviation		5.14379498
Most Extreme Differences	Absolute		.101
	Positive		.101
	Negative		-.086
Test Statistic			.101
Asymp. Sig. (2-tailed)[c]			.200[d]
Monte Carlo Sig. (2-tailed)[e]	Sig.		.158
	99% Confidence Interval	Lower Bound	.148
		Upper Bound	.167

a. Test distribution is Normal.

b. Calculated from data.

c. Lilliefors Significance Correction.

d. This is a lower bound of the true significance.

e. Lilliefors' method based on 10000 Monte Carlo samples with starting seed 299883525.

Figure 4. Result of Normality Test

The results of the two-way ANOVA analysis are presented in Figure 5 as follows:

Test Between-Subjects Effects

Dependent Variable: Learning outcome

Source	Type III Sum of Squares	df1	Mean Square	F	Sig.
Corrected Model	1494.966[a]	3	4.325	19	<,001
Intercept	102722.931	1	5.679	9	<,001
Method	474.205	1	6.880	28	<,001
Learning Motivation	134.900	1	2.828	2	.002
Method*Learning Motivation	185.890	1	1.804	26	<,001
Error	684.016	52	1.833	28	
Total	246247.000	56	4.277	21	
Corrected Total	2178.982	55	7.302	35	

a.R Squared= .686 (adjusted R Squared==.668)

Figure 5. Results of two-way ANOVA analysis

Two-way ANOVA revealed significant effects of learning model ($F = 36.13$, $p < .001$), learning motivation ($F = 10.26$, $p = .002$), and their interaction ($F = 14.13$, $p < .001$). ANOVA's two-way analysis indicates that the learning model has a significant effect on students' geometry learning outcomes with a

significance value of <0.001. Problem-Based Learning resulted Game-based learning still indicates a positive contribution in higher learning outcomes than game-based learning. Learning motivation also has a significant effect on geometry learning outcomes with a significance value of 0.002. In addition, there was a significant interaction between the learning model and learning motivation on students' geometry learning outcomes with a significance value of <0.001.

4. DISCUSSION

The results of the study indicate that Problem-Based Learning is more effective than game-based learning in improving the mathematics learning outcomes of elementary school students in geometry (building space) materials. These findings indicate that problem-based learning is able to encourage students to be actively involved in the learning process through exploration, discussion, and problem-solving activities. Problem-based geometry learning allows students to build knowledge through more meaningful and contextual learning experiences that help improve the conceptual understanding of elementary school students. Problem-Based Learning helps students actively build knowledge through authentic problem-solving experiences in elementary school mathematics learning (Ahmad et al., 2023). The findings of this study also support the results of research which shows that PBL has a significant influence on improving mathematics learning outcomes of elementary school students (Wayan et al., 2024).

Problem-Based Learning helps students develop problem-solving and mathematical reasoning skills through investigation activities into real problems. In elementary school mathematics learning, the use of contextual problems helps students connect mathematical concepts with everyday experiences so that the learning process becomes more meaningful. Problem-solving skills are an important ability in mathematics learning because they help students develop logical and analytical thinking skills in solving contextual problems (Amalina & Vidakovich, 2023). In addition, problem-based learning also supports the development of higher-order thinking skills and critical thinking skills of elementary school students (Anazifa & Djukri, 2017).

Problem-Based Learning also has a positive impact on student learner engagement. This is possible because PBL carries out discussion, collaboration, and problem exploration activities in PBL to encourage students to be more active and focused during the learning process. These findings are in line with research (Anugraheni et al., 2026) that shows that Problem-Based Learning is able to increase the behavioral engagement and emotional engagement of elementary school students through collaborative learning activities and contextual problem-solving. High student engagement helps students have better attention, participation, and learning engagement so as to support the improvement of mathematics learning outcomes of elementary school students.

PBL may outperform game-based learning because it requires students to engage in deeper cognitive processing, including problem analysis, hypothesis generation, and solution evaluation. Game-based learning also demonstrated a positive contribution to elementary school math learning. The use of educational board games is able to create a fun, interactive, and learning atmosphere that increases student learning motivation. Game-based learning is able to increase motivation, positive attitudes towards mathematics, and learning outcomes of elementary school students through more exploratory and collaborative learning activities (White & McCoy, 2019). Authentic context-based game-based learning is able to improve students' motivation and mathematics learning outcomes through interactive and fun learning experiences (Bang et al., 2023; Wang et al., 2018). Digital games also have a positive impact on the learning motivation and math achievement of K–12 students (Byun & Joung, 2018; Morgan, 2022).

In learning mathematics of building space materials, the use of educational games helps students understand spatial concepts more concretely through visualization and object manipulation activities. Students often have difficulty understanding the relationship between two-dimensional and three-dimensional shapes so learning geometry requires richer visual and manipulative learning experiences (Sharma, 2024). The use of educational board games provides opportunities for students to learn through play, exploration, and social interaction activities to help students understand the concept of building a space in a more concrete and fun way. Gamification in elementary school geometry learning

is able to increase students' interest in learning and help understand spatial concepts more effectively (Puig et al., 2022)

The results of the study also show that learning motivation has a significant effect on students' mathematics learning outcomes. Learning motivation is an important factor because it affects students' attention, perseverance, and persistence during the learning process. Motivation and involvement have a direct relationship to the mathematics learning outcomes of elementary school students. Students with high learning motivation tend to have more active involvement and better problem-solving skills in mathematics learning (Xia et al., 2022) In addition, game-based learning has also been proven to be able to increase students' learning motivation through a more fun and interactive learning experience (Wang et al., 2018; White & McCoy, 2019)

In addition to the main influence of each variable, this study also found an interaction between learning models and learning motivation on students' mathematics learning outcomes. These findings show that the effectiveness of the learning model is influenced by the characteristics of students' learning motivation. Students with high learning motivation tend to show more active participation and better adaptability to problem-based learning and game-based learning. Therefore, teachers need to consider the condition of students' learning motivation in determining appropriate learning strategies so that the learning process becomes more optimal and meaningful.

From the perspective of educational technology, the results of this study imply that problem-based active learning designs and educational games can be used as an alternative to elementary school mathematics learning strategies that are more learner-centered and interactive. The integration of Problem-Based Learning and game-based learning is able to create a more active, contextual, and appropriate learning experience in accordance with the developmental characteristics of elementary school students. In addition, the results of this study also strengthen the importance of developing educational technology-based mathematics learning innovations to improve learner engagement, learning motivation, and mathematics learning outcomes of elementary school students.

Limited and Future Research

This research has several limitations, including the relatively limited number of samples and the implementation of research that was only conducted in one elementary school. In addition, the educational games used are still based on non-digital board games, so further research is recommended to develop digital game-based learning or adaptive gamification for elementary school mathematics learning with a wider sample coverage. A fascinating idea for further research emerged from the findings that certain games may support specific mathematical concepts (Brezovszky et al., 2019), indicating that some games might be better suited for learning particular mathematical concepts.

CONCLUSION

This study indicate that Problem-Based Learning has a more effective influence than game-based learning on the geometry learning outcomes in building space materials. Problem-based learning helps students to be more active in building knowledge through exploration, discussion, and problem-solving activities so as to increase conceptual understanding and student learning engagement. These findings reinforce the view that geometry needs to be designed in a learner-centered and contextual manner to be able to help students understand abstract geometry concepts in a more meaningful way (Ahmad et al., 2023; Amalina & Vidakovich, 2023).

This study also demonstrated helps students understand three-dimensional geometric concepts that game-based learning continues to make a positive contribution to geometry learning, especially in increasing learning motivation, student participation, and a more enjoyable learning atmosphere. The use of educational board games helps students understand the concept of building space through visualization activities, object manipulation, and concrete learning experiences that are in accordance with the developmental characteristics of elementary school students (Sharma, 2024; White & McCoy, 2019). Thus, game-based learning has great potential to support more interactive and engaging mathematics learning in primary education (Brezovszky et al., 2019). Learning motivation has been proven to have a significant influence on students' geometry learning outcomes. Students with high learning motivation tend to indicate more active learning engagement, better attention, and higher

persistence in completing geometry learning tasks. These findings reinforce research (Xia et al., 2022) which explains that motivation and engagement are closely related to the academic achievement of elementary school students.

This study also found that there is an interaction between learning model and learning motivation on students' geometry learning. This indicate that the effectiveness of the learning model is influenced by the characteristics of students' learning motivation so that teachers need to consider psychological conditions and student learning involvement in determining appropriate mathematics learning strategies.

From the perspective of educational technology, the results of this study imply that the integration of Problem-Based Learning and game-based learning can be an alternative to a more active, learner-centered, and interactive elementary school mathematics learning design. Problem-based learning and educational games are able to create a learning experience that is more contextual, fun, and in accordance with the developmental characteristics of elementary school students. Therefore, the development of educational technology-based mathematics learning innovations needs to continue to be carried out to increase learner engagement, learning motivation, and learning outcomes of elementary school students. The novelty of this study lies in the direct comparison between PBL and board game-based learning for lower-grade geometry instruction while simultaneously examining the moderating role of learning motivation.

Author Contributions:
Conceptualization, [THL, INSD, NCS]; **Methodology**, [INSD, THL]; **Software,** [THL)]; **Validation**, [THL, NCS]; **Formal Analysis**, [THL]; **Investigation**, [THL]; **Resources**, [THL]; **Data Curation**, [THL]; **Writing—Original Draft Preparation**, [THL, NCS]; **Writing—Review & Editing**, [NCS]; **Visualization**, [NCS]; **Supervision**, [INSD, NCS]; All authors have read and agreed to the published version of the manuscript.

CONFLICT OF INTEREST STATEMENT
The authors declared no conflict of interest related to the conduct, authorship, and publication of this study

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