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Implementation of problem-based learning using domino cards to increase learning activity and achievement mathematics

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Abstract. Limited classroom participation and low mathematics achievement remain challenges in early elementary education. This study examined (1) the effect of Problem-Based Learning (PBL) using domino cards on mathematics learning activity, (2) its effect on mathematics achievement, and (3) its simultaneous effect on both outcomes. The population comprised 40 first-grade students at SDN 2 Plosorejo, Blora Regency, Indonesia. Using purposive sampling, 20 students participated in each group. A quantitative quasi-experimental method with a Nonequivalent Control Group Pretest–Posttest Design was employed. Learning activity was measured through classroom observation, while achievement was assessed using a 10-item mathematics test. Data were analyzed using descriptive statistics, MANOVA, and univariate analysis. The experimental group obtained higher mean scores for learning activity ($M = 88.55$) and achievement ($M = 82.15$) than the control group ($M = 78.55$ and $M = 71.35$). PBL using domino cards significantly affected learning activity, $F(1, 38) = 103.289$, $p < .001$, and achievement, $F(1, 38) = 29.062$, $p < .001$. The simultaneous effect was significant, $F(2, 37) = 55.431$, $p < .001$. These findings indicate that PBL using domino cards enhances participation and achievement. Teachers are recommended to integrate domino cards into PBL as a practical medium for early mathematics learning.

Introduction

Children growing up in a world increasingly shaped by quantitative information, technological advancement, and complex everyday decision-making need strong mathematical numeracy skills. Numeracy extends beyond performing calculations; it involves interpreting quantitative information, reasoning mathematically, and applying mathematical knowledge to meaningful real-life problems. The importance of these competencies is reflected in Sustainable Development Goal 4 (SDG 4), which emphasizes inclusive and equitable quality education and the development of essential foundational skills, including literacy and numeracy (UNESCO, 2024).

However, developing mathematical competence remains a persistent challenge in education. Programme for International Student Assessment (PISA) results indicate that many students still struggle to apply mathematical knowledge and reasoning to unfamiliar situations, showing that mathematical competence requires more than procedural mastery (OECD, 2023). These challenges highlight the importance of developing meaningful mathematics learning from the early grades, when students begin to establish foundational mathematical understanding, learning habits, and attitudes toward mathematics. Evidence from mathematics education also indicates that game-based learning can support mathematics achievement by giving students opportunities to actively engage with mathematical tasks rather than passively receive information (Tokac et al., 2023; Widana & Laksitasari, 2023). Therefore, strengthening mathematics learning at the elementary level is essential for establishing the foundation for students' subsequent mathematical development.

The challenge is particularly evident in first-grade elementary classrooms, where mathematics learning provides the foundation for students' subsequent mathematical development. At this stage, students need opportunities to develop fundamental mathematical concepts through concrete experiences and active participation; however, classroom instruction may still position students as recipients of teacher guidance rather than active participants in the learning process. Preliminary observations in the experimental class at SDN 2 Plosorejo revealed a substantial achievement problem: only 4 of 20 first-grade students (20%) achieved the Minimum Learning Competency Criteria (KKTP), while 16 students (80%) had not yet reached the expected level of mathematics achievement. Classroom observations also showed that many students tended to wait for teacher guidance, were reluctant to express mathematical ideas, and demonstrated limited involvement during mathematics learning activities. These conditions indicate that the problem involves not only students' mathematics achievement but also their participation in the learning process, highlighting the urgency of implementing an instructional approach that can actively engage students while supporting the development of foundational mathematical competencies (Asilevi et al., 2024; Ma & Chen, 2024; Z. Zhang & Crawford, 2024).

The need to transform students from passive recipients of information into active participants in knowledge construction highlights the relevance of student-centered instructional approaches. Problem-Based Learning (PBL) is theoretically relevant to this problem because it engages students in meaningful problems that require them to investigate information, discuss possible solutions, collaborate with peers, and construct knowledge through problem-solving. A systematic review by Anazifa & Djukri (2023) reported that PBL provides a learning environment conducive to developing thinking skills through direct engagement in problem-solving processes. This approach is also consistent with evidence from primary education showing that inquiry-oriented learning can provide richer opportunities for students' learning skills and classroom participation than teacher-centered instruction (Asilevi et al., 2024). However, PBL alone may be challenging for first-grade students when mathematical problems are presented abstractly because young learners need concrete representations to connect mathematical ideas with observable experiences. Therefore, learning media that provide tangible and interactive representations can strengthen the implementation of PBL.

Game-based learning has been associated with increased student engagement because challenge, interaction, and active involvement are incorporated into learning activities (Nadeem et al., 2023). Educational games can also support learning outcomes when game activities are deliberately aligned with instructional objectives rather than used merely for entertainment (Dabbous et al., 2023). Similarly, card-based learning activities provide tangible opportunities for students to interact, communicate, and participate in structured learning tasks (Borko & Putnam, 2022). Thus, integrating concrete domino cards into PBL can provide a practical bridge between problem-solving, mathematical representation, and active student participation in early-grade mathematics learning.

Despite the potential of PBL and game-based learning, several issues remain unresolved in the existing literature. First, research on active and collaborative learning in primary education has frequently been situated in science, inquiry, project-based learning, or technology-supported contexts. For example, collaborative invention projects have demonstrated how primary students can construct knowledge through collective activity, but such evidence has largely emerged from science-related learning environments (Sormunen et al., 2023). Studies of collaborative project-based learning have similarly emphasized integrated learning and teachers' experiences rather than the specific demands of early-grade mathematics instruction (Kati et al., 2023). Second, a substantial part of recent game-based learning research has moved toward digital environments.

Collaborative game design can develop valuable student competencies (Laakso et al., 2021), while research on game literacy has further demonstrated the educational possibilities of designed game environments. However, these developments do not eliminate the need for simple manipulatives that can be implemented without sophisticated devices or technological infrastructure. Third, existing studies commonly examine learning activity, engagement, or achievement as separate outcomes, leaving limited evidence on whether a single instructional intervention produces a significant multivariate effect across students' observable mathematics learning activity and achievement. Therefore, empirical evidence remains limited regarding the integration of PBL with concrete domino card media in first-grade mathematics, particularly when mathematics learning activity and achievement are examined simultaneously (Jäder & Johansson, 2025).

The present study addresses these gaps by integrating Problem-Based Learning with domino card media in first-grade elementary mathematics instruction. Its primary novelty lies not merely in adding a game to PBL, but in assigning domino cards a pedagogical function within the problem-solving process. The cards provide visible and manipulable representations that students can use while interpreting problems, exploring numerical relationships, communicating possible solutions, and working with peers. This approach is consistent with evidence that visual representation and appropriate instructional scaffolding can support mathematical understanding when learners move between representations and mathematical (L. Zhang et al., 2025). Unlike technology-intensive game-based interventions, domino cards are low-cost, reusable, and classroom-accessible manipulatives that can be incorporated into face-to-face instruction without dependence on digital infrastructure.

Recent research has emphasized that technology itself does not guarantee meaningful learning; instructional design and the ways learners participate in learning remain central to educational effectiveness (Sailer et al., 2023). Beyond the instructional innovation, this study contributes empirically by examining mathematics learning activity and mathematics achievement simultaneously within the same quasi-experimental intervention. This multivariate perspective enables the study to determine whether PBL assisted by domino card media is associated with differences across both students' learning activity and achievement rather than evaluating these outcomes independently (Smith et al., 2022; Ariyanti et al., 2025; Ernawati et al., 2024).

Accordingly, the central research problem is whether Problem-Based Learning assisted by domino card media produces higher mathematics learning activity and mathematics achievement among first-grade elementary students than conventional instruction. The study therefore has three objectives: (1) to examine the effect of PBL assisted by domino card media on students' mathematics learning activity, (2) to examine its effect on students' mathematics achievement, and (3) to determine its simultaneous effect on mathematics learning activity and mathematics achievement. These objectives are investigated through a quasi-experimental comparison between students receiving PBL assisted by domino cards and those receiving conventional instruction, an approach appropriate when educational interventions are implemented in naturally occurring classroom groups rather than through individual random assignment (Denny et al., 2023). Based on the conceptual arguments and empirical evidence discussed above, three hypotheses are proposed: H1, students taught through PBL assisted by domino card media will demonstrate significantly higher mathematics learning activity than students receiving conventional instruction; H2, they will demonstrate significantly higher mathematics achievement; and H3, PBL assisted by domino card media will have a significant multivariate effect on the combined outcomes of mathematics learning activity and mathematics achievement.

Method

Research Method and Design

A quantitative quasi-experimental design was employed to examine the effects of Problem-Based Learning (PBL) assisted by domino card media on first-graders' mathematics learning activity and mathematics achievement. Quantitative measurement enabled objective comparison of the two dependent variables between the experimental and control groups (Creswell & Creswell, 2023). A Nonequivalent Control Group Pretest–Posttest Design was employed. The experimental group received PBL-based mathematics instruction supported by domino card media, whereas the control group received conventional mathematics instruction. Both groups completed mathematics achievement pretests and posttests, and researchers observed mathematics learning activities during classroom instruction. The study maintained intact classroom groups because individual random assignment was not feasible in the school setting (Buckler & Moore, 2023). The independent variable was Problem-Based Learning assisted by domino card media, while the dependent variables were mathematics learning activity and mathematics achievement. MANOVA was selected as the primary inferential procedure because it examined one independent variable against two related dependent variables simultaneously.

Table 1. Research Variables and Data Analysis

Component	Description
Independent variable (X)	Problem-Based Learning assisted by domino card media
Dependent variable 1 (Y1)	Mathematics learning activity
Dependent variable 2 (Y2)	Mathematics achievement
Experimental group	PBL assisted by domino card media
Control group	Conventional mathematics instruction
Research design	Nonequivalent Control Group Pretest–Posttest Design
Primary statistical analysis	MANOVA
Multivariate statistic	Pillai's Trace
Follow-up analysis	Univariate analysis
Effect size	Partial eta squared (ηp^2)

Participants and Sampling Technique

First-grade students from SDN 2 Plosorejo, Kunduran District, Blora Regency, Central Java, Indonesia, participated in the study during the 2025/2026 academic year. Forty students participated: 20 in the experimental group and 20 in the control group. We selected intact classroom groups using purposive sampling because individual random assignment was not feasible in the school setting (Denny et al., 2023). One class served as the experimental group and received PBL assisted by domino card media, whereas the other class served as the control group and received conventional mathematics instruction.

Both groups received equivalent mathematics content, instructional duration, pretest procedures, and posttest procedures. Classroom observations were conducted during mathematics instruction to measure students' learning activity.

Research Setting and Timeline

SDN 2 Plosorejo, Kunduran District, Blora Regency, Central Java, Indonesia, served as the research setting during the second semester of the 2025/2026 academic year. Two parallel first-grade classes were selected as the experimental and control groups.

The instructional intervention focused on addition within 10, consistent with the first-grade mathematics curriculum. Research activities included preparation, instrument development and validation, pretest administration, instructional intervention, classroom observation, posttest administration, and statistical analysis.

Research Procedures

Research implementation comprised preparation, instrument validation, pretesting, instructional intervention, observation, posttesting, and data analysis. Preliminary observations and teacher discussions identified instructional needs, followed by the development of PBL-based lesson plans, materials, and instruments using domino card media. After expert validation, equivalent pretests were administered to both groups. The experimental group received PBL with domino card media, while the control group received conventional instruction. Learning activities were observed during the intervention, followed by posttests. Data were analyzed using descriptive statistics, Shapiro–Wilk, Levene's, Box's M, MANOVA, and follow-up univariate analyses.Image 1 presents the complete research procedure workflow.

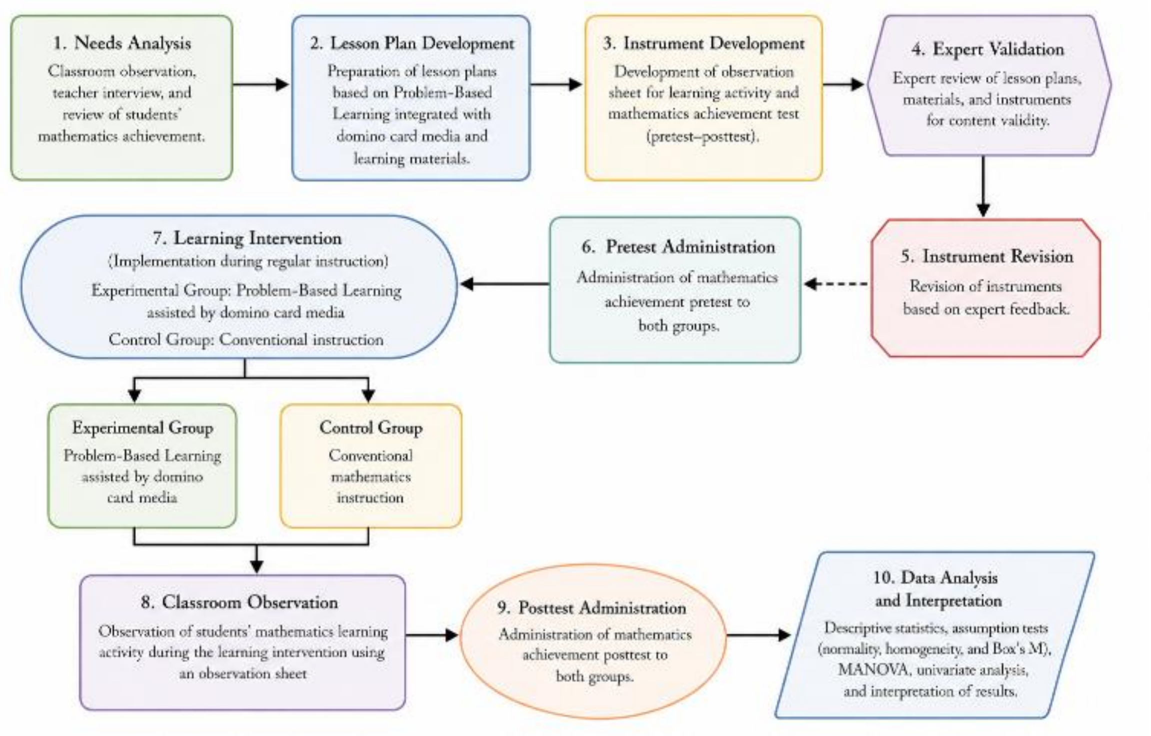

Image 1. Research Procedures for the Quasi-Experimental Study

Research Procedure Description

Research procedures involved nine stages: needs analysis, development of lesson plans, materials, and instruments, expert validation and revision, pretesting, intervention, implementation monitoring, posttesting, and data analysis. The experimental group received PBL assisted by domino card media, while the control group received conventional instruction. Two independent observers monitored treatment fidelity. After the intervention, posttests, motivation questionnaires, and observations were administered. Data were then coded and analyzed using descriptive statistics, assumption tests, independent-samples *t*-tests, and effect-size analysis.

Data Collection Techniques and Research Instruments

Two research instruments were used to measure the dependent variables: a classroom observation sheet to assess mathematics learning activity and a mathematics achievement test to assess students' mastery of addition within 10. The instruments were developed based on the research objectives, learning indicators, and characteristics of first-grade mathematics instruction. The observation sheet used a four-point rating scale, whereas the achievement test consisted of 10 items. The instrument blueprint was prepared to ensure alignment between the measured indicators, instruments, and intended research outcomes.

Table 3. Research Instrument

Research Outcome	Instrument	Indicator	Item/Aspect	Scale
Mathematics learning activity	Classroom observation sheet	Visual activity	Observing domino cards, learning materials, and problem representations	1–4
Mathematics learning activity	Classroom observation sheet	Oral activity	Asking questions, answering questions, and expressing mathematical ideas	1–4
Mathematics learning activity	Classroom observation sheet	Motor activity	Manipulating domino cards and participating in learning tasks	1–4
Mathematics learning activity	Classroom observation sheet	Mental activity	Thinking, identifying relationships, and solving mathematical problems	1–4
Mathematics learning activity	Classroom observation sheet	Emotional activity	Showing interest, enthusiasm, confidence, and persistence	1–4
Mathematics achievement	Mathematics achievement test	Understanding addition within 10	Applying addition concepts to mathematical problems	10 items
Mathematics achievement	Mathematics achievement test	Problem solving	Solving addition problems presented in contextual situations	

Instrument Validity Testing

Experts validated the research instruments before data collection, including a mathematics learning activity observation sheet and a 10-item mathematics achievement test. The observation sheet assessed visual, oral, motor, mental, and emotional activities, while the test measured mastery of addition within 10. Experts evaluated relevance, clarity, content suitability, language, and alignment using a four-point scale. Validity was calculated as the percentage of obtained versus maximum scores. The researchers revised instruments based on expert recommendations before use.

Table 4. Results of Research Instrument Validation

Research Instrument	Number of Items	Validator	Validity Result	Criterion	Decision
Mathematics learning activity observation sheet	10	Expert 1	89%	Very valid	Valid
Mathematics learning activity observation sheet	10	Expert 2	87%	Very valid	Valid
Mathematics achievement test	10	Expert 1	86%	Very valid	Valid

The expert validation results indicate that the mathematics learning activity observation sheet obtained validity scores of 89% and 87%, while the mathematics achievement test obtained a validity score of 86%. All instruments reached the very valid category. The results indicate that the instruments demonstrated adequate relevance, clarity, content suitability, language, and alignment with the research objectives.

The validation findings also confirm the instruments' suitability for measuring the two intended research outcomes. The observation sheet was appropriate for assessing students' participation and involvement during mathematics learning, whereas the 10-item achievement test was appropriate for measuring students' mastery of addition within 10. The validated instruments were subsequently used in the data collection process.

Data Analysis Techniques and Criteria

Descriptive Statistics

We calculated means and standard deviations for mathematics learning activity and achievement in both groups.

Assumption Testing

MANOVA assumptions were tested using Shapiro–Wilk for normality, Levene's test for homogeneity of variances, and Box's M for homogeneity of covariance matrices. A value of $p > .05$ indicated that the assumption was met. Pillai's Trace was selected as the primary multivariate statistic due to its robustness.

MANOVA

MANOVA was used to examine the effect of the treatment on mathematics learning activity and achievement simultaneously. Statistical significance was set at $\alpha = .05$ ($p < .05$), with partial eta squared (ηp^2) reported as the effect size.

Follow-Up Analysis

A significant MANOVA result was followed by univariate Tests of Between-Subjects Effects for each dependent variable. F, degrees of freedom, p-value, and ηp^2 were reported. Independent-samples t-tests were not used as the primary analysis.

Effect Size

Partial eta squared (ηp^2) indicated the magnitude of treatment effects on the combined and individual dependent variables.

Research Ethics

Research authorization was obtained from the school before data collection. Activities followed regular instruction without additional risks. Participant identities were protected through anonymous coding, and findings were reported in aggregate. Equivalent content, instructional duration, and assessment procedures were maintained across groups.

Results and Discussion

Results

Equivalence of the Experimental and Control Groups

Before administering the treatment, the initial mathematics achievement of the experimental and control groups was examined using pretest scores. Both groups consisted of 20 first-grade students. The experimental group received Problem-Based Learning (PBL) using domino cards, whereas the control group received conventional mathematics instruction.

An independent-samples t-test was conducted to determine whether the two groups differed significantly in pretest scores before the intervention. The analysis used a significance level of 0.05. A *p*-value greater than 0.05 indicates that the difference between the groups is not statistically significant, suggesting comparable initial mathematics achievement.

Table 5. Equivalence Test of Experimental and Control Groups Based on Pretest Scores

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
	Equal variances assumed	0.01	0.97	0.41	38	0.68	0.55	1.34	-2.16	3.26
Pre test	Equal variances not assumed			0.41	37.90	0.68	0.55	1.34	-2.16	3.26

Table 5 shows that Levene's test was not significant (F = 0.001, p = 0.973), indicating homogeneous variances between the two groups. Therefore, the Equal variances assumed row was used for the independent-samples t-test. The test produced t (38) = 0.410, p = 0.684, which is greater than 0.05. The result indicates no statistically significant difference in pretest mathematics achievement between the experimental and control groups. Therefore, the two groups were statistically equivalent before the treatment, providing an appropriate baseline for comparing their learning outcomes after the intervention.

Learning Implementation and Instructional Syntax

The treatment involved Problem-Based Learning (PBL) using domino cards in the experimental class, whereas the control class received conventional mathematics instruction. Both classes addressed the same mathematics learning objectives and content, while the instructional approaches and learning media differed. PBL activities emphasized problem solving, student collaboration, and active engagement with domino cards as a concrete learning medium.

Application of PBL in the experimental class followed the stages of presenting mathematical problems, organizing students for learning, guiding investigation and problem solving, developing and presenting solutions, and evaluating the problem-solving process. Domino cards supported students in connecting mathematical concepts with concrete and visual representations. Conventional instruction in the control class involved teacher explanations, examples, guided practice, individual exercises, and evaluation.

Table 6. Learning Syntax of the Experimental and Control Classes

Learning Stage	Experimental Class: PBL Using Domino Cards	Control Class: Conventional Instruction
Introduction	The teacher introduces the mathematics topic, connects the lesson with students' prior knowledge, and explains the learning objectives.	The teacher introduces the topic, recalls students' prior knowledge, and explains the learning objectives.
Presenting the Problem	The teacher presents contextual mathematics problems and introduces	The teacher explains the mathematics concepts and

	domino cards as the learning medium. Students identify and discuss the problems.	presents examples of problems.
Organizing Students for Learning	The teacher organizes students into groups and provides domino cards and problem-solving tasks.	The teacher provides learning materials and assigns exercises to students.
Guiding Investigation and Problem Solving	Students manipulate domino cards, discuss possible solutions, match mathematical representations, and solve problems collaboratively. The teacher provides guidance when necessary.	Students solve exercises based on the teacher's explanations. The teacher provides guidance and clarification during the activities.
Developing and Presenting Solutions	Students discuss their solutions and present their group results. Class members compare and respond to the presented solutions.	Students report or submit their answers. The teacher leads the discussion and provides corrections.
Evaluating the Learning Process	The teacher and students review the solutions, evaluate the problem-solving process, and formulate learning conclusions.	The teacher reviews students' answers, reinforces mathematics concepts, provides corrections, and concludes the lesson.

Comparison of the instructional procedures indicates that PBL using domino cards emphasized problem solving, collaboration, active participation, and concrete mathematical representations, whereas conventional instruction emphasized teacher explanation, guided practice, and individual exercises. Differences in learning activities provided the instructional basis for examining the effects of PBL using domino cards on mathematics learning activity and achievement.

Descriptive Statistics of Learning Activity and Mathematics Achievement

Descriptive statistics were calculated to provide an initial overview of students' performance before conducting the hypothesis tests. Summary statistics for each research variable are presented in Table 7.

Table 7. Descriptive Statistics of Learning Activity and Learning Achievement

Class		Learning activities	Learning achievement
Experimental	Mean	88.55	82.15
	N	20	20
	Std. Deviation	3.18	7.65
	Minimum	83.00	67.00
	Maximum	94.00	95.00
Control	Mean	78.55	71.35
	N	20	20
	Std. Deviation	3.03	4.65
	Minimum	74.00	64.00
	Maximum	84.00	82.00
Total	Mean	83.55	76.75
	N	40	40
	Std. Deviation	8.30	
	Minimum	74.00	64.00
	Maximum	94.00	95.00

Table 7 shows higher mean scores in the experimental group for learning activity (M = 88.55, SD = 3.18) and mathematics achievement (M = 82.15, SD = 7.65) than in the control group (M = 78.55, SD = 3.03; M = 71.35, SD = 4.65). The mean differences were 10.00 and 10.80 points, respectively. These descriptive results indicate better performance following PBL using domino cards. We then conducted further analysis after testing the required assumptions.

Assumption Testing

Assumption testing began with the normality test to determine whether each dependent variable satisfied the distributional requirements for parametric analysis. Results of the Shapiro–Wilk normality test are presented in Table 6.

Table 8. Shapiro–Wilk Normality Test

	Class	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	Df	Sig.	Statistic	df	Sig.
Learning activities	Experimental	0.08	20	0.20*	0.97	20	0.78
	Control	0.10	20	0.20*	0.96	20	0.55
Learning achievement	Experimental	0.10	20	0.20*	0.94	20	0.32
	Control	0.09	20	0.20*	0.97	20	0.89

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

Table 8 shows that all Shapiro–Wilk significance values exceeded .05 (p = .32–.89). Thus, learning activity and mathematics achievement were normally distributed in both groups, satisfying the normality assumption for MANOVA.

Homogeneity of Variance Test

Independent-Samples t-Test of Mathematics Learning Activity

An independent-samples t-test was conducted to determine whether mathematics learning activity differed significantly between the experimental and control groups. The results are presented in Table 9.

Table 9. Independent-Samples t-Test of Mathematics Learning Activity

		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Learning activities	Equal variances assumed	0.03	0.84	10.16	38	0.00	10.00	0.98	8.00	11.99
	Equal variances not assumed			10.16	37.90	0.00	10.00	0.98	8.00	11.99

The result shows a significant difference in mathematics learning activity between the experimental and control groups, $t(38) = 10.16$, $p < .001$, with a mean difference of 10.00 points.

Independent-Samples t-Test of Learning Motivation

An independent-samples t-test was conducted to determine whether learning motivation differed significantly between the experimental and control groups. The results are presented in Table 10.

Table 10. Independent-Samples t-Test of Learning Motivation

		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Learning motivation	Equal variances assumed	0.08	0.76	8.74	38	0.00	8.55	0.97	6.57	10.52
	Equal variances not assumed			8.74	37.84	0.00	8.55	0.97	6.57	10.52

The results indicate a significant difference in learning motivation between the experimental and control groups, $t(38) = 8.74, p < .001$, with a mean difference of 8.55 points.

Homogeneity of Covariance Matrices

Box's M test was conducted to examine the equality of covariance matrices across the experimental and control groups.

Table 11. Box's Test of Equality of Covariance Matrices

Box's Test of Equality of Covariance Matrices[a]	
Box's M	7.95
F	2.50
df1	3
df2	259920.00
Sig.	0.06

The Box's M test was nonsignificant, $F(3, 25) = 2.50, p = 0.06$ (> .05), indicating homogeneous covariance matrices across the experimental and control groups. Thus, the MANOVA covariance assumption was satisfied.

Multivariate Effect of PBL Assisted by Domino Card Media

Pillai's Trace was used to examine the simultaneous effect of PBL assisted by domino card media on mathematics learning activity and mathematics achievement.

Table 12. Multivariate Tests of the Effect of PBL Assisted by Domino Card Media

Multivariate Tests	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Pillai's trace	0.75	55.43[a]	2.00	37.00	.00	.75
Wilks' lambda	0.25	55.43[a]	2.00	37.00	.00	.75
Hotelling's trace	2.99	55.43[a]	2.00	37.00	.00	.75
Roy's largest root	2.99	55.43[a]	2.00	37.00	.00	.75

Each F tests the multivariate effect of Kelas. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.
a. Exact statistic

Pillai's Trace showed a significant simultaneous effect of PBL using domino cards on mathematics learning activity and achievement, $F(2, 37) = 55.431$, $p < .001$, partial $\eta^2 = .750$. Thus, the third hypothesis was supported.

Follow-Up Univariate Effects of PBL Assisted by Domino Card Media

We conducted follow-up univariate analyses after the significant MANOVA result to examine the effect of PBL assisted by domino card media on each dependent variable separately.

Table 13. Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[c]
Corrected Model	Learning_activities	1000.00[a]	1	1000.000	103.28	.000	0.73	103.28	1.000
	postes	1166.40[b]	1	1166.40	29.062	.000	0.43	29.062	1.000
Intercept	Learning_activities	279224.10	1	279224.10	28840.76	.000	0.99	28840.76	1.000
	postes	235622.500	1	235622.50	5870.86	.000	0.99	5870.86	1.000
Kelas	Learning_activities	1000.00	1	1000.000	103.28	.000	0.73	103.28	1.000
	postes	1166.40	1	1166.40	29.062	.000	.43	29.06	1.000
Error	Learning_activities	367.90	38	9.68					
	postes	1525.10	38	40.13					
Total	Learning_activities	280592.000	40						
	postes	238314.00	40						
Corrected Total	Learning_activities	1367.90	39						
	postes	2691.50	39						

a. R Squared = .731 (Adjusted R Squared = .724)

b. R Squared = .433 (Adjusted R Squared = .418)

c. Computed using alpha = .05

Follow-up univariate analyses showed significant effects of PBL assisted by domino card media on mathematics learning activity, $F(1, 38) = 103.289$, $p < .001$, partial $\eta^2 = .731$, and mathematics achievement, $F(1, 38) = 29.062$, $p < .001$, partial $\eta^2 = .433$. Both dependent variables therefore differed significantly between the experimental and control groups, confirming the specific effects identified following the significant multivariate result.

Discussion

PBL using domino cards significantly improved students' mathematics learning activity, as indicated by the higher activity score in the experimental group and the significant univariate effect, $F(1, 38) = 103.289$, $p < .001$, partial $\eta^2 = .731$. PBL encourages students to actively solve problems, discuss solutions, and collaborate, while domino cards provide concrete and engaging representations appropriate for first-grade learners. The finding supports previous research showing that PBL and game-based learning can promote active student participation (Lei et al., 2024). The result also reinforces the theoretical basis that active problem solving combined with concrete learning media can reduce passive learning behavior and increase classroom engagement (Camacho-Sánchez et al., 2023).

Mathematics achievement was significantly higher in the experimental group than in the control group, $F(1, 38) = 29.062$, $p < .001$, partial $\eta^2 = .433$. Problem solving requires students to apply mathematical concepts, while domino cards allow learners to manipulate and connect mathematical representations directly. Such learning experiences can facilitate conceptual understanding among young learners. The finding is consistent with previous studies reporting positive effects of educational games and interactive learning on learning outcomes Koski et al. (2023); Rodrigues et al. (2024) Consequently, the present findings support the theoretical proposition that combining an active instructional model with concrete media can improve mathematics achievement (Li & Sun, 2024; Widana et al., 2021).

PBL using domino cards also produced a significant simultaneous effect on mathematics learning activity and achievement, Pillai's Trace = .750, $F(2, 37) = 55.431$, $p < .001$, partial $\eta^2 = .750$. The strong multivariate effect indicates that increased participation and improved achievement occurred together rather than as isolated outcomes (Quane & Ní Ríordáin, 2025). The novelty of the study lies in integrating domino card media into PBL for first-grade mathematics while examining learning activity and achievement simultaneously. The finding extends previous research by demonstrating that a simple concrete card medium can function not merely as a game, but as a supporting component of problem-based learning that connects active participation with academic achievement.

The findings theoretically strengthen the application of PBL and concrete learning media in early mathematics education by showing their complementary contribution to active participation and achievement. Practically, teachers can integrate domino cards into PBL as an accessible, low-cost, and concrete medium for facilitating discussion, problem solving, and mathematical practice. Nevertheless, the study was conducted with 40 first-grade students in one school using a quasi-experimental design, which limits the generalizability of the findings. Future research should involve larger and more diverse samples, longer intervention periods, and different mathematical topics to examine the consistency and wider applicability of the approach.

Conclusion

Problem-Based Learning assisted by domino card media positively affected first-grade students' mathematics learning activity and achievement. Using domino cards in the PBL process encouraged students to participate actively in problem solving, discussion, manipulation of concrete mathematical representations, and communication of mathematical ideas. The intervention also improved students' understanding of foundational addition concepts. Overall, integrating domino card media into PBL provided a concrete, student-centred learning approach that supported both mathematics learning activity and achievement in first-grade classrooms.

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