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Integrating Ludo Games into Mathematics Instruction: A Strategy to Boost Elementary Students' Mathematical Literacy

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Abstract: Mathematical literacy among Indonesian students remains a concern, and whole number instruction delivered mainly through lectures offers limited opportunities for students to formulate, employ, and interpret mathematics in meaningful contexts. This study aims to examine whether and how an educational Ludo game based on whole numbers improves the mathematical literacy of fifth grade students, using a quasi-experimental one-group pretest-posttest design with 40 students from two classes in Surabaya, Indonesia. The Game-Based Learning stages were apperception, concept demonstration, game implementation, mathematical strategy reflection, and concept reinforcement, and the data were analyzed using N-Gain, the Shapiro-Wilk test, the Wilcoxon signed-rank test, and an effect size estimate. The results showed that 65% of students reached the medium or high N-Gain category, that posttest scores differed significantly from pretest scores ($|Z| = 5.124$, $p < 0.001$, $r = 0.81$), and that 35% of students remained in the low category, which suggests that the Ludo game can serve as a low-cost non-digital strategy for strengthening mathematical literacy when it is accompanied by structured scaffolding.

Keywords: Educational Ludo; Whole Numbers; Mathematical Literacy; Game-Based Learning; Elementary School.

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INTRODUCTION

Mathematical literacy is commonly described as the capacity to formulate, employ, and interpret mathematics in real-life contexts, and it continues to attract attention in Indonesian mathematics education (Wijaya et al., 2024). Evidence from Wijaya et al. (2024) indicates that the 2022 Programme for International Student Assessment (PISA) mathematics score declined by 13 points relative to 2018, and the authors explored the perspectives of Indonesian mathematics teachers on the factors contributing to this result. These patterns place pressure on schools to strengthen students' ability to use mathematics in context, beginning in the elementary grades. Whole number learning is a natural entry point for this effort, because number operations and relations underpin many of the situations in which elementary students first apply mathematics.

Early number competence provides the foundation on which later mathematics learning is built. DePascale et al. (2023) tested tablet-based games targeting numerical knowledge and working memory with 235 kindergarten children and reported that children who played both games showed the most pronounced and sustained benefits in mathematical knowledge. Research by Chang (2023) examined how early numeracy and literacy skills are associated with fourth grade mathematics achievement, which underscores the long reach of early numerical understanding. Evidence from Graven and Jorgensen (2024) on number stories with marginalised families further shows that opportunities to engage with number can be created in accessible everyday forms.

Research on elementary mathematics instruction has examined concrete representations as one resource for supporting students' understanding of number. Ahmad and Siller (2024) investigated the effect of concrete and virtual manipulatives on mathematics achievement for diverse achievement level groups. In the specific case of place value, Ergül and Dogan (2022) examined game-based learning in primary school place value teaching with a mixed-method design. These studies position concrete and game-based materials as practical resources for whole number instruction in the primary grades.

Board games combine concrete materials with rule-governed activity, which makes them a distinct form of manipulative-based learning. Estrada-Plana et al. (2024) conducted a quasi-experimental study with 234 third and fourth grade children and reported medium to large effect sizes for number operations and number ranking among third graders who played mathematical board games, compared with a control group. Evidence from Gasteiger and Moeller (2021) indicates that conventional board games such as Parcheesi, played with traditional number dice, benefited counting skills and the ability to recognize and use structures among children aged four to six years, and the structure effect was still present one year later. Taken together, these studies suggest that board games with numerical features can support number-related skills across several age groups (Estrada-Plana et al., 2024; Gasteiger & Moeller, 2021).

Beyond board games, empirical studies have examined game-based learning in mathematics through several formats. Christopoulos et al. (2024) investigated whether immersion in 3D virtual games was associated with improvement in mathematical ability

within game-based learning. Chatzaki et al. (2024) explored the potential of a game-based preschool assessment of mathematical competencies. These studies indicate that game-based learning is a recognized strategy, while the evidence on specific game formats and grade levels continues to develop.

Non-digital games hold a prominent place in primary classroom practice. Russo et al. (2023) identified the characteristics of non-digital mathematical games that educators value most, which informs the design of classroom-ready games. Debrenti (2024) compared non-digital and digital game-based learning in primary mathematics and reported that students enjoyed task solving in both formats, which supports the classroom relevance of low-cost non-digital options. Such findings point to the value of examining how specific non-digital games function in particular grade levels and content areas.

Much of the evidence on number-based games has been gathered with preschool and early primary children. Vlassis et al. (2023) addressed arithmetic development in kindergarten through a game-based approach, and Jylänki et al. (2023) targeted the early numeracy of preschoolers through a combined intervention in a pilot study. Gasteiger and Moeller (2021) and DePascale et al. (2023) likewise worked with children in the preschool and kindergarten age range. Less attention has been directed toward upper elementary classrooms where whole number operations connect with mathematical literacy processes.

Studies of mathematical board games have often been reported in terms of design and development procedures. As an example, Fathurrohman et al. (2022) reported the design and development of conventional and digital mathematical board games for learning arithmetic. These reports describe game features in detail, and outcome evidence for specific designs in upper elementary classes continues to accumulate. Research remains limited regarding how a whole number Ludo game contributes to mathematical literacy outcomes in upper elementary classes when those outcomes are evaluated with gain scores, nonparametric inferential testing, and effect size estimation.

Existing studies have primarily examined number-based board games with preschool and early primary children, and the contribution of a whole number Ludo game to the mathematical literacy of upper elementary students remains underexplored. This study addresses an underexplored aspect of non-digital game-based learning by evaluating an educational Ludo game based on whole numbers in fifth grade mathematics instruction in Indonesia. This study extends previous research by examining mathematical literacy gains using N-Gain categories, the Wilcoxon signed-rank test, and an effect size estimate within a quasi-experimental one-group pretest-posttest design. This study aims to examine whether and how the educational Ludo game based on whole numbers improves the mathematical literacy of fifth grade elementary school students, with attention to conceptual understanding, reasoning, representation, and problem solving.

Based on the aim stated above, this study addresses three research questions: 1) What is the distribution of N-Gain categories in students' mathematical literacy after learning with the educational Ludo game based on whole numbers? 2) Is there a

significant difference between students' pretest and posttest mathematical literacy scores, and how large is the effect? 3) How can the variation in students' gains be interpreted in relation to the structure of the Ludo-based Game-Based Learning stages?

METHODS

Research Design and Participants

This study employed a quasi-experimental design with a one-group pretest-posttest model, in which students' mathematical literacy was measured before and after the learning intervention. According to Maciejewski (2020), quasi-experimental designs resemble randomized trials in many respects, and the absence of randomization introduces internal validity threats that must be considered when interpreting results. The participants were 40 fifth grade students from two classes in Surabaya, Indonesia, and both classes received the same intervention without a control class. Table 1 summarizes the main components of the research design and context so that readers can see the scope of the study at a glance.

Table 1. Overview of the Research Design and Context

Component	Description
Research approach	Quantitative, quasi-experimental
Design	One-group pretest-posttest (O1 X O2)
Participants	40 fifth grade students from two classes
Location	Surabaya, Indonesia
Intervention	Educational Ludo game based on whole numbers
Learning model	Game-Based Learning with five stages
Outcome variable	Mathematical literacy
Comparison class	None
Supplementary data	Classroom observation of engagement, interaction, and implementation quality

Table 1 shows that the study combined a single treatment condition with repeated measurement of one outcome, namely mathematical literacy. It was included to state the design boundaries explicitly, including the absence of a control class, so that the claims made later in the article can be matched to the design. For readers, this clarity supports a realistic reading of causal language and helps them judge the transferability of the findings to similar classrooms. For researchers who intend to replicate the study, the table also provides a compact checklist of design elements to be reproduced.

Research Procedure

The study followed a sequence of pretest, intervention, posttest, and analysis, which is the standard flow of a one-group pretest-posttest design. According to Handley et al. (2018), the validity of pre-post designs depends on careful attention to design, execution, and analysis, which makes a clear description of the procedure important. Observations were also conducted throughout the learning process to monitor cognitive engagement, student interaction, and the quality of the implementation of the game media. Figure 1 presents this procedure as a flow diagram.

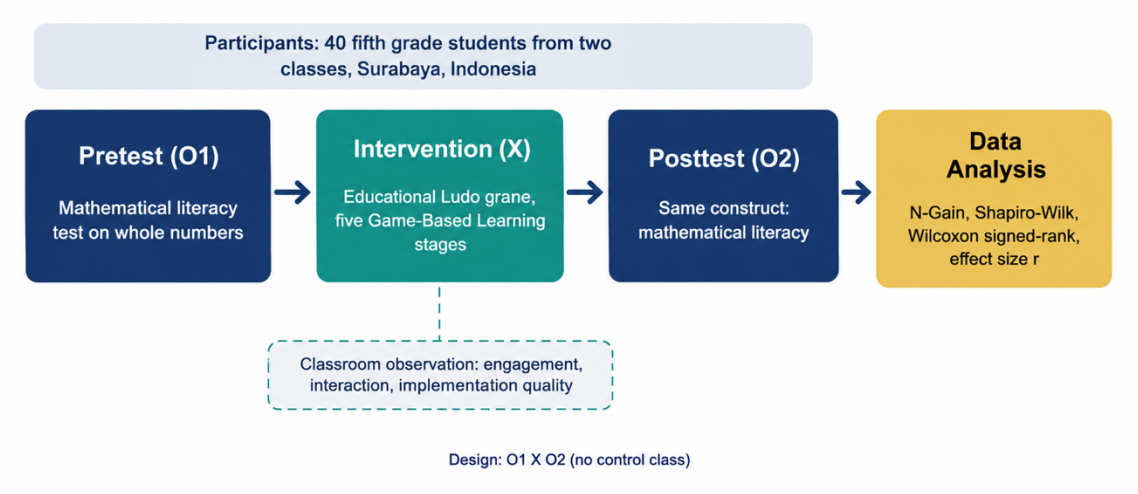


Figure 1. Research Procedure of the One-Group Pretest-Posttest Design

Figure 1 shows that each student contributed one pretest score and one posttest score, which were linked through the single intervention phase. The figure was included to present the logic of measurement and analysis visually, since a flow diagram is easier to follow than a narrative description alone. Readers benefit because they can locate each data source and each analysis within the overall workflow, which reduces ambiguity about when measurements were taken. The diagram also supports teachers who wish to adapt the procedure, because the sequence of stages can be reused in other whole number lessons.

Intervention: Educational Ludo and Game-Based Learning Syntax

The intervention used an educational Ludo game based on whole numbers, in which dice rolls, pawn movements, and board positions were linked to whole number tasks. Evidence from Gasteiger and Moeller (2021) shows that conventional board games with number dice can support numerical competencies, and the Ludo format retains these dice and board features. The lesson followed the Game-Based Learning (GBL) syntax of apperception, concept demonstration, game implementation, mathematical strategy reflection, and concept reinforcement. Table 2 describes what occurred at each stage and how each stage relates to mathematical literacy.

Table 2. Game-Based Learning Stages of the Educational Ludo Lesson

Stage	Main activity	Link to mathematical literacy
1. Apperception	The teacher activates prior knowledge of whole numbers, place value, and operations through short questions and everyday examples.	Prepares the knowledge needed to formulate problems
2. Concept demonstration	The teacher demonstrates the board, dice, pawns, and rules, and shows how each move can be written as a number statement.	Models the representation of situations with numbers

3. Game implementation	Students play Ludo, roll the dice, move pawns, and solve whole number tasks linked to board positions.	Employing whole number operations and procedures
4. Mathematical strategy reflection	Students explain their moves and strategies and interpret the meaning of pawn positions under the game rules.	Interpreting results and reasoning about strategies
5. Concept reinforcement	The teacher summarizes the key concepts and gives consolidation tasks.	Consolidating conceptual understanding and problem solving

Table 2 shows that the stages move from activating prior knowledge, through modeling and play, to reflection and consolidation. It was included because the instructional sequence is the active component of the intervention, and its description allows the results to be linked to specific classroom activities. Readers benefit by seeing how formulating, employing, and interpreting processes were given a place in the lesson, which clarifies why literacy gains could be expected. Teachers benefit from the table as a practical lesson outline that can be adapted without additional equipment beyond a board, dice, and pawns.

Instrument and Data Analysis

Mathematical literacy was measured with a pretest and a posttest on whole number content, covering conceptual understanding, reasoning, representation, and problem solving, in line with the formulating, employing, and interpreting processes. Improvement was expressed as N-Gain, which Hake (1998) defined as the ratio of the actual gain to the maximum possible gain. Normality was checked with the Shapiro-Wilk test, which Ghasemi and Zahediasl (2012) note is recommended by common statistical software for samples smaller than 50, and the paired difference was tested with the Wilcoxon signed-rank test, with effect size r estimated as described by Fritz et al. (2012). Table 3 lists each analysis, its purpose, and its decision rule, together with the hypotheses tested.

Table 3. Data Analysis Plan and Decision Rules

Analysis	Purpose	Formula or decision rule
N-Gain	Classify the level of improvement for each student	g = (posttest - pretest) / (maximum score - pretest). High: $g > 0.70$. Medium: $0.30 \leq g \leq 0.70$. Low: $g < 0.30$
Shapiro-Wilk test	Check the normality of pretest and posttest scores	Data are normal if $p > 0.05$
Wilcoxon signed-rank test	Test the difference between paired pretest and posttest scores	H0: no difference in mathematical literacy before and after the intervention. H1: there is a difference. Reject H0 if $p < 0.05$
Effect size r	Estimate the magnitude of the difference	$r = \text{abs}(Z) / \sqrt{N}$. Benchmarks: 0.10 small, 0.30 medium, 0.50 large

Table 3 shows that the analytical plan moved from describing improvement to testing its significance and then to estimating its magnitude. It was included to fix the decision rules before the results are presented, which allows readers to verify that conclusions follow from stated criteria. Readers benefit because the thresholds used for

N-Gain categories, normality, significance, and effect size are available in one place. The table also lets other researchers reproduce the analysis with comparable data from their own classrooms.

RESULTS

Distribution of N-Gain Categories

The first analysis examined how much each student's mathematical literacy improved by converting pretest and posttest scores into N-Gain values. The N-Gain values were classified into high, medium, and low categories using the criteria presented in Table 3. Table 4 presents the number and percentage of students in each category so that the distribution of improvement across the 40 students can be seen at a glance. This presentation allows the reader to judge both the overall direction of change and the variation among students.

Table 4. Categories of Students' Mathematical Literacy N-Gain

N-Gain category	Score range	Number of students	Percentage (%)
High	$g > 0.70$	10	25
Medium	$0.30 \leq g \leq 0.70$	16	40
Low	$g < 0.30$	14	35
Total		40	100
Medium and high combined		26	65

Table 4 shows that 10 students (25%) reached the high category, 16 students (40%) reached the medium category, and 14 students (35%) remained in the low category. Combined, 26 of the 40 students (65%) achieved medium or high gains, which indicates that improvement was common in the two classes. The table was included because a mean gain alone would conceal the presence of students who benefited less from the activity. For the reader, this distribution offers a basis for judging the practical value of the Ludo game and for planning additional support for the students in the low category.

To complement the tabulated frequencies, the distribution of N-Gain categories is visualized in Figure 2. The figure displays the proportion of students in each category as a bar chart with percentages labeled on each bar. A visual summary is useful because the relative size of the three groups can be compared without reading each number. The figure also highlights the combined share of students in the medium and high categories.

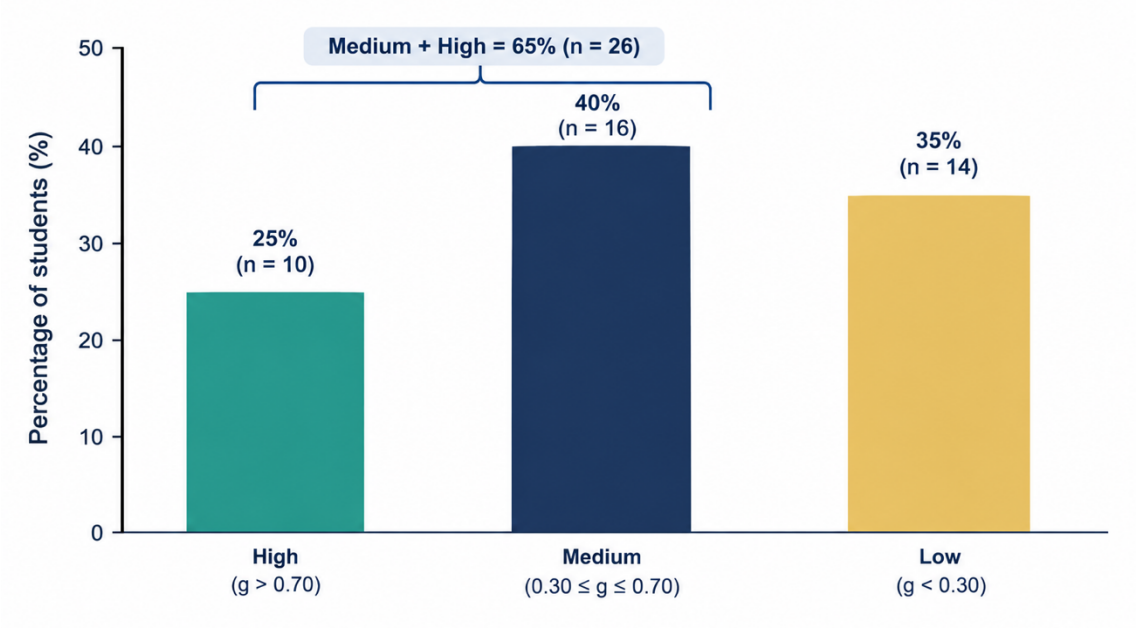


Figure 2. Distribution of Students' Mathematical Literacy N-Gain Categories (N = 40)

Figure 2 shows that the medium category forms the largest group, followed by the low and high categories. The medium and high categories together exceed the low category by a clear margin, which supports the interpretation that most students benefited from the intervention. This visual was included to help readers grasp the shape of the distribution quickly, especially readers who scan the results before reading the tables. For teachers and researchers, it also signals that a single Ludo intervention produced different levels of gain, which leads to the discussion of differentiated support.

Normality Test

Before selecting the inferential test, the distribution of pretest and posttest scores was examined with the Shapiro-Wilk test at a significance level of 0.05. This step determines whether a parametric or a nonparametric test is appropriate for the paired data. Table 5 reports the Shapiro-Wilk statistics and significance values for both measurement points. Presenting these values allows readers to verify the basis on which the analytical decision was made.

Table 5. Results of the Shapiro-Wilk Normality Test

Data	Statistic (W)	Significance (p)	Interpretation
Pretest	0.952	0.107	Normally distributed
Posttest	0.812	< 0.001	Not normally distributed

The pretest scores were normally distributed (W = 0.952, p = 0.107), and the posttest scores deviated from normality (W = 0.812, p < 0.001). Because one of the two data sets did not meet the normality assumption, the Wilcoxon signed-rank test was selected for the hypothesis test. The table was included to make the analytical path transparent and to protect the credibility of the inferential result. Readers benefit because they can see that the choice of test followed the characteristics of the data, which is

consistent with the guidance that normality should be checked before parametric procedures are applied (Ghasemi & Zahediasl, 2012).

Wilcoxon Signed-Rank Test

The next analysis tested whether the difference between pretest and posttest scores was statistically significant. The Wilcoxon signed-rank test was applied to the 40 paired observations, and the effect size *r* was computed from the *Z* statistic. Table 6 reports the test statistic, the two-tailed significance value, the effect size, and the hypothesis decision. This table gives readers the central inferential evidence of the study in one place.

Table 6. Results of the Wilcoxon Signed-Rank Test

Comparison	*Z*	Significance (2-tailed)	Effect size *r*	Decision
Posttest - Pretest	-5.124	< 0.001	0.81	H0 rejected, H1 accepted

Note. r = abs(Z) / √N, with N = 40 paired cases. When N is taken as the 80 total observations, r = 0.57, which also falls in the large range.

The test produced $|Z| = 5.124$ with $p < 0.001$, so the null hypothesis of no difference was rejected and the alternative hypothesis was accepted. The effect size *r* was 0.81 when computed from the 40 paired cases, which falls in the large range according to the conventional benchmarks described by Fritz et al. (2012). The table was included because a significance value alone does not communicate the magnitude of change. Readers can therefore judge both the statistical significance and the practical size of the improvement, and researchers can compare the estimate with other studies that report effect sizes.

To summarize the sequence of analyses, Figure 3 presents the decision path from normality testing to the final conclusion. The figure links each statistical step with the specific result obtained in this study. This visual representation is intended to help readers trace how the evidence accumulated across the three analyses. It also clarifies the logic by which the nonparametric test was chosen.

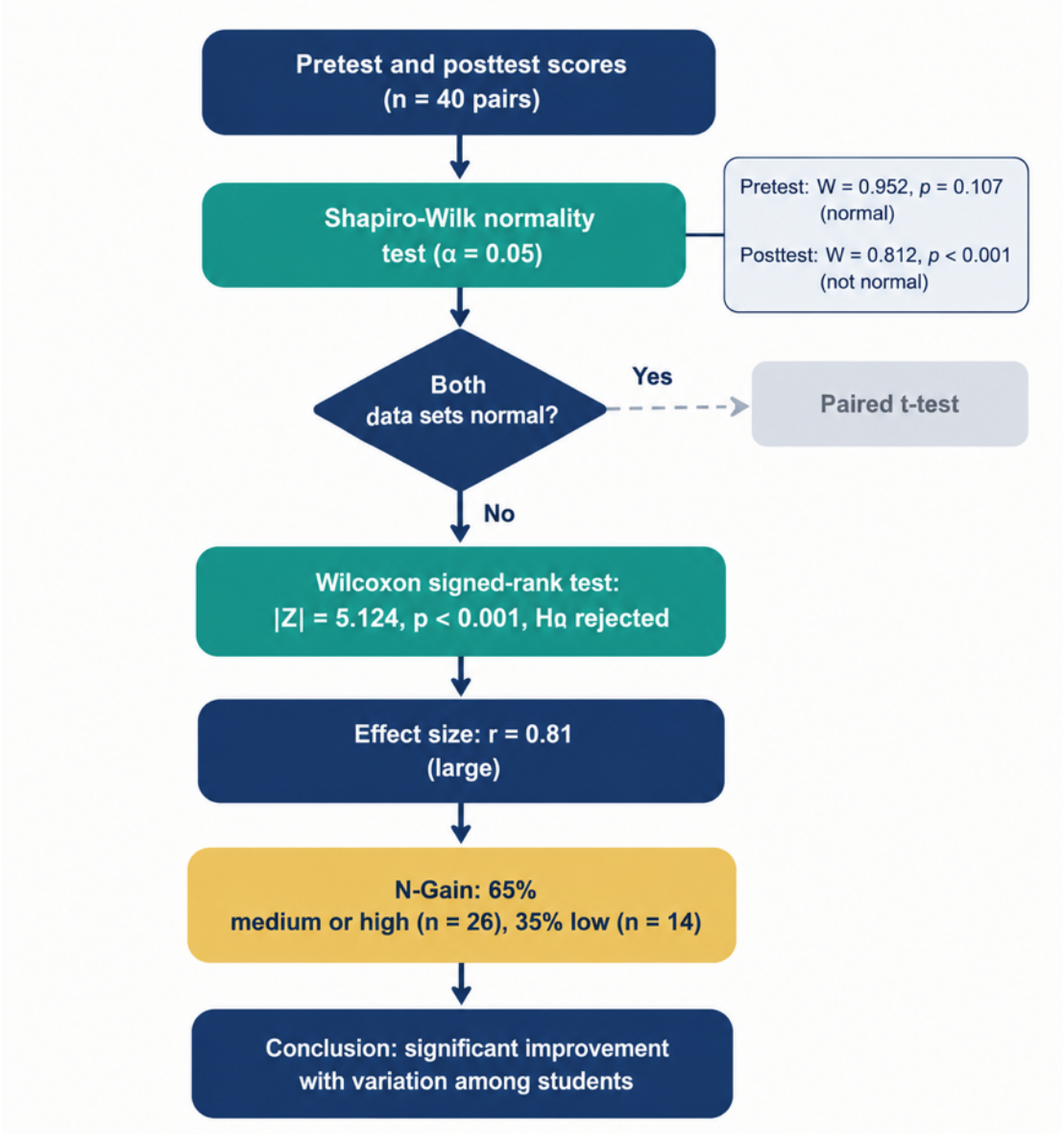


Figure 3. Analytical Decision Path and Key Results

Figure 3 shows that the distribution of N-Gain categories, the Shapiro-Wilk results, and the Wilcoxon test converge on the same direction of improvement. The figure was included because readers of an applied mathematics education journal often seek a compact view of the analytical workflow that can be reused in their own classroom studies. Its main benefit is that it makes the chain of reasoning from data to conclusion visible without requiring the reader to compare several tables. The figure also shows that the improvement is accompanied by variation among students, which is examined in the Discussion.

DISCUSSION

Overall Improvement in Mathematical Literacy

The first major finding is that mathematical literacy scores differed significantly between pretest and posttest ($|Z| = 5.124$, $p < 0.001$, $r = 0.81$), and 65% of students reached the medium or high N-Gain category. A plausible explanation is that Ludo places whole number operations inside a repeated cycle of dice rolling, counting, and moving pawns, which gives students many short opportunities to practice number relations in a meaningful setting. This pattern is consistent with the cluster randomized trial by Vita-Barrull et al. (2024), in which primary school students who played modern board games during school hours showed greater improvements in updating and in academic skills, including mathematics, than students in regular classes. The present findings extend this line of evidence to fifth grade students and to a literacy-oriented outcome, and they resemble the higher achievement reported by Lin and Cheng (2022) for sixth grade students who reviewed prime factorization concepts through a board game.

Zainuddin et al. (2020) reported that students perceived gamified exercises in a formal learning context as fun, motivating, and engaging, which offers one explanation for how repeated Ludo turns may sustain participation, although engagement was not analyzed as an outcome in the present study. Board game applications in physics and chemistry classes also reported favorable attitudes, motivation, and engagement among students (Dziob, 2020; Li et al., 2022). The magnitude of improvement observed here should be interpreted with care because the present study used a one-group design, an effect size computed from paired ranks, and a specific classroom context, and no comparison class was included, unlike the designs of Vita-Barrull et al. (2024) and Lin and Cheng (2022). Evidence from Szilágyi et al. (2025) on non-digital game-based learning among university computer science students suggests that such approaches are examined across educational levels, so the practical implication is that teachers can consider Ludo as a low-cost option while treating the magnitude of gain as context dependent.

Mathematical Literacy Processes in Ludo

The second major finding is that most students gained in mathematical literacy, which can be interpreted through the formulating, employing, and interpreting processes that Ludo activates. In each turn, students decide which move to pursue (formulating), carry out whole number operations to reach a position (employing), and interpret the meaning of a pawn position within the game rules (interpreting), so the game structure mirrors the processes assessed in the literacy test. This explanation aligns with Russo et al. (2021), who examined how primary teachers use games to support the teaching of mathematics and thereby indicated that games are an established part of primary mathematics classrooms. Szabo et al. (2020) presented examples of problem-solving strategies in mathematics education in relation to 21st-century skills, and the present results add quantitative evidence on a literacy outcome for whole number content that draws on strategic reasoning.

The pattern of gains also fits the literature on concrete materials, since the board, dice, and pawns provide physical referents for number relations that students can manipulate and discuss. Li et al. (2022) reported that a chemistry board game promoted interaction and discussion among students, which parallels the mathematical talk that the strategy reflection stage was designed to elicit. Ni et al. (2021) examined the implementation and efficacy of a teacher intervention in dialogic mathematics classroom discourse in primary schools, which indicates that the way teachers guide talk deserves attention alongside the materials themselves. Interpreted together, these findings imply that Ludo can work well when the game is embedded in a sequence that includes demonstration, reflection, and reinforcement, and the attention of May (2022) to spaced, repeated retrieval practice for mathematical knowledge and reasoning is consistent with the role of consolidation tasks in the fifth stage.

Variation in Gains

The third major finding is that 35% of students remained in the low N-Gain category, which shows that the benefits of the intervention were unevenly distributed. One plausible explanation concerns affective factors, because Halme et al. (2022) found, among 406 fifth and sixth grade students, that state and trait mathematics anxiety showed negative relations with performance that varied with the type of mathematical task. Lin and Wang (2022) reported that, among 39 primary students playing a technology-enhanced board game, high-achieving students found the game more entertaining and low-achieving students might feel somewhat challenged, and Bicer et al. (2020) examined mathematical creative self-efficacy together with problem posing, although none of anxiety, prior achievement, or self-efficacy was measured in the present study. These explanations remain tentative, and the variation should be understood in relation to differences in prior knowledge, affective factors, and game participation that were not directly measured.

Differentiated support therefore appears to be a reasonable implication of the findings. Hwang et al. (2021) examined the effects of a social regulation-based online learning framework on students' learning achievements and behaviors in mathematics, which points to the structured regulation of learning as a design feature worth considering. Although that framework was implemented online, it suggests that teacher scaffolding, tiered task cards, and brief diagnostic checks of number sense could be built into non-digital Ludo lessons to support students who gain less. Other active approaches, such as the project-based learning examined by Rehman et al. (2024) in relation to 21st-century skills and student engagement in the math classroom, may be explored in combination with Ludo to extend literacy development beyond whole number operations.

Limitations

Several limitations should be considered when interpreting the findings. The one-group pretest-posttest design cannot rule out the influence of maturation, repeated testing, or concurrent classroom events, because quasi-experimental designs face internal validity threats in the absence of randomization (Maciejewski, 2020). According to Handley et al. (2018), strategies such as designs with nonequivalent comparison groups can strengthen both internal and external validity, which supports the recommendation to include a

comparison class in future studies. The sample of 40 students from two classes in one city limits generalization, and N-Gain was originally formulated for average course gains (Hake, 1998), so student-level categories should be interpreted with caution.

CONCLUSION

This study examined whether and how an educational Ludo game based on whole numbers improves the mathematical literacy of fifth grade students in Surabaya, Indonesia. The results showed that 65% of the 40 students reached the medium or high N-Gain category and that posttest scores differed significantly from pretest scores ($|Z| = 5.124$, $p < 0.001$, $r = 0.81$). The 35% of students in the low category indicates that gains were uneven, and the effectiveness of the game may depend on prior number competence and the quality of structured support. These findings suggest that Ludo can serve as a low-cost non-digital strategy to support mathematical literacy in whole number instruction when it is implemented through the five Game-Based Learning stages.

For classroom practice, teachers may adopt the five-stage sequence and add scaffolding such as guided questioning and tiered tasks for students with lower initial number sense. For research, future studies should include a comparison class or randomized allocation to strengthen causal inference. Future studies should also measure motivation, mathematical self-efficacy, and math anxiety alongside literacy outcomes, which would help explain why some students gain less. Delayed posttests and replication in other regions would clarify whether the gains persist and whether the pattern observed in this study holds in different classroom contexts.

AI Use Statement

AI-assisted tools were used, where applicable, for language refinement and proofreading. The authors reviewed the manuscript and take responsibility for its content.

Author Contributions

MRY: conceptualization, research design, data collection, data analysis, and initial manuscript preparation. HNK: data collection, data analysis, and interpretation of findings. AS: research methodology, supervision, and manuscript revision. ZA: data interpretation, critical review, and manuscript editing. HZ: methodological review, interpretation of findings, and critical revision of the manuscript. All authors approved the final manuscript.

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Conflict of Interest

The authors declare no competing interests.

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