



The effect of traditional *congklak* game-based learning on the numeracy achievement of second-grade elementary students

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Article info	Abstract
<p>Keywords: <i>Congklak</i>, elementary students, game-based learning, numeracy, second-grade.</p>	<p>This study examines the effect of traditional game-based learning with <i>Congklak</i> on numeracy achievement among second-grade elementary students. The study addresses the limited availability of experimental evidence on culturally grounded, non-digital games for early numeracy instruction. A pre-test–post-test control-group design was employed with 60 students (aged 7–8 years) from a public elementary school in Indonesia. Participants were assigned to either an experimental group receiving <i>Congklak</i>-based numeracy instruction or a control group receiving conventional textbook-based instruction for four weeks. Numeracy achievement was measured using the Numeracy Achievement Test (NAT), consisting of 30 dichotomously scored items covering number recognition, counting skills, and logical reasoning (score range 0–100; reliability coefficient $\alpha = 0.82$). Data were analyzed using paired-samples and independent-samples t-tests. Results indicated significant pre-test–post-test improvement in both groups ($p < .001$). However, the experimental group achieved higher post-test scores ($M = 78.47$, $SD = 6.92$) than the control group ($M = 66.13$, $SD = 7.25$), with a statistically significant between-group difference, $t(58) = 4.96$, $p < .001$, $d = 1.27$. These findings suggest that integrating traditional <i>Congklak</i>-based activities into mathematics instruction can support early numeracy development through culturally responsive and play-based learning experiences.</p>

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1. Introduction

Numeracy is widely recognized as a foundational competency that shapes children's academic development and their skills to engage with quantitative aspects of everyday life. Beyond basic arithmetic operations such as addition and subtraction, numeracy involves reasoning with numbers, recognizing patterns, and applying mathematical understanding to real-world situations. Internationally, numeracy is defined as the capacity to access, use, interpret, and communicate mathematical information to solve practical problems and make informed decisions (Kogoya et al., 2023; Yantoro et al., 2021). In early primary education, numeracy provides the basis for later mathematical learning, logical thinking, and problem-solving, and is closely linked to broader educational outcomes.

Despite its importance, evidence from international large-scale assessments indicates that numeracy achievement remains uneven across countries. Results from the Programme for International Student Assessment (PISA) consistently show that students in many low- and middle-income countries, including Indonesia, perform below the OECD average in mathematics (Muslimin, 2020; T. T. Wijaya, 2022). These outcomes have raised sustained concerns regarding the effectiveness of early mathematics instruction and the need for pedagogical approaches that better support conceptual understanding and student engagement from the earliest grades.

One explanation frequently discussed in the literature relates to the dominance of teacher-centred, drill-based instructional practices in elementary mathematics classrooms. While such approaches may support procedural fluency, they often provide limited opportunities for students to actively construct meaning or connect mathematical ideas to lived experiences. As a result, mathematics may be perceived as abstract and disconnected from daily life, which can negatively affect motivation and engagement, both of which are critical for sustained learning in early childhood education.

In response to these challenges, game-based learning has gained increasing attention as an instructional approach that integrates cognitive, motivational, and social dimensions of learning. Research in educational psychology emphasizes that play is not merely recreational but also serves as a meaningful context for cognitive development, supporting attention, memory, and reasoning. In mathematics education, game-based learning situates numerical concepts within interactive activities governed by rules and goals, allowing learners to explore strategies, receive feedback, and construct understanding through experience. Empirical studies across different contexts have reported positive associations between structured game-based activities and early numeracy outcomes, including improved number sense, problem-solving, and learner engagement.

However, much of the existing game-based learning literature has focused on digital or computer-based games, particularly in Western educational contexts. In contrast, traditional non-digital games, which are culturally embedded, socially interactive, and physically engaging, have received comparatively less attention in experimental research (Lei et al., 2022; Lestari et al., 2021; Syamsuddin et al., 2021). Studies on board games and linear number games have demonstrated that such games can support number sense and arithmetic development among young learners, suggesting that physical and social interaction may play an essential role in early mathematical learning. These findings highlight the potential of traditional games as instructional tools, especially in contexts where digital resources are limited.

Within the Indonesian cultural context, *Congklak*, also known internationally as Mancala or *Sungka*, is a traditional counting and strategy game that inherently involves numerical operations. Players distribute seeds across pits according to fixed numerical rules, requiring counting,

anticipation, and simple strategic reasoning. Based on a learning perspective, *Congklak* offers repeated opportunities for one-to-one correspondence, sequencing, addition, and subtraction through concrete manipulation. Such characteristics align with cognitive-developmental theories that emphasize the importance of hands-on experiences for learners in the concrete operational stage. Previous studies have explored *Congklak* in relation to social interaction, character development, and general mathematical understanding, indicating its pedagogical promise (Barz et al., 2023; Susanti, 2020).

Nevertheless, despite this growing interest, empirical evidence on the direct impact of *Congklak*-based instruction on measurable numeracy outcomes remains limited. Many are descriptive or qualitative, focus on early childhood settings, or lack rigorous experimental designs capable of supporting causal inference. Moreover, relatively few studies have examined *Congklak*-based learning specifically within formal elementary mathematics instruction using controlled pre-test–post-test comparisons. As a result, the instructional value of *Congklak* for improving numeracy achievement at the primary school level has not yet been sufficiently established through quantitative experimental research.

Addressing this gap is particularly relevant in the current educational landscape. Concerns have been raised that increased reliance on screen-based learning may reduce opportunities for physical interaction and culturally meaningful engagement, especially for young learners. Traditional games offer an alternative that integrates cognitive learning with social interaction and cultural continuity. Based on a broader perspective, the use of culturally grounded instructional approaches is also consistent with international policy frameworks, such as the United Nations' Sustainable Development Goal 4, which emphasizes inclusive and equitable quality education that respects cultural diversity (Lin & Cheng, 2022; Toharudin et al., 2021; Wardoyo et al., 2021).

Against this background, the present study adopts an experimental approach to examine the effect of traditional game-based learning using *Congklak* on the numeracy achievement of Grade II elementary students. The intervention integrates arithmetic and simple problem-solving activities into structured *Congklak* gameplay over a four-week period, while a comparison group receives conventional textbook-based instruction covering the same curricular content. By employing a pre-test–post-test control-group design and a standardized numeracy assessment, this study aims to provide empirical evidence on whether *Congklak*-based instruction is associated with differences in numeracy outcomes in a formal classroom setting.

Accordingly, the research purpose is to investigate the effect of *Congklak*-based game learning on the numeracy achievement of second-grade elementary students, with a specific focus on basic arithmetic and simple problem-solving skills. By situating *Congklak* within both international game-based learning research and local cultural practice, this study seeks to contribute to the literature on culturally responsive pedagogy and to offer evidence-based insights for educators exploring alternative approaches to early mathematics instruction.

2. Method

This study employed a pre-test–post-test control-group design to examine the effect of traditional game-based learning using *Congklak* on students' numeracy achievement. Given the school's natural classroom structure, group assignments were conducted at the class level rather than at the individual student level. Two intact Grade II classes were randomly assigned to either the experimental condition (*Congklak*-based learning) or the control condition (conventional textbook-based instruction). Therefore, the design can be classified as a cluster-based experimental design with pre-test and post-test measures (Rais et al., 2025).

The general model for this design is represented as:

Group	Pretest	Treatment	Posttest
Experimental	O ₁	X	O ₂
Control	O ₃	-	O ₄

Figure 1. Students engaged in *congklak*-based numeracy learning activity

Where O₁ and O₃ represent pretest scores, O₂ and O₄ represent post-test scores, and X represents the treatment (*Congklak*-based learning). The comparison of post-test means between the groups indicates the treatment effect, while pre-test–post-test differences within each group measure internal improvement.

The participants were 60 Grade II elementary students (aged 7–8 years), consisting of 30 males and 30 females, from a public elementary school in Yogyakarta, Indonesia. Two intact classes participated in the study, with each class comprising 30 students. One class was assigned to the experimental group, and the other to the control group through simple random assignment at the class level.

All participants had completed the same Grade I mathematics curriculum and were following the national elementary mathematics curriculum during the study period. No students had been identified as having learning disabilities or special educational needs that would prevent participation in numeracy instruction. Attendance was monitored throughout the intervention, and all students completed both the pre-test and post-test; therefore, no attrition occurred during the study.

The assessment of students' numeracy achievement focused on three key aspects aligned with the national primary mathematics curriculum and the intervention's objectives. These aspects reflect the core components of early numeracy development: number recognition, counting accuracy, and logical reasoning, each of which was directly related to the arithmetic and problem-solving skills integrated into the *Congklak*-based learning activities (Jannah et al., 2023). The assessment criteria are summarized in Table 1.

Table 1. Assessment of students' numeracy achievement

No.	Aspects	Indicators	Description of Assessment	Score Range
1.	Number Recognition	Students can recognize and write numbers correctly up to 100	Identify and write numbers presented in sequence or random order	0–1 per item
2.	Counting Skills	Students can count objects or quantities accurately	Count the total objects shown in pictures or <i>Congklak</i> seeds	0–1 per item
3.	Logical Reasoning	Students can choose correct operations and strategies to reach solutions	Predict the following number or the optimal move in a game scenario	0–1 per item

Content validity of the NAT was established through expert judgment involving three specialists in elementary mathematics education and educational measurement. The experts evaluated item relevance, clarity, and alignment with curriculum objectives and numeracy indicators. Based on their feedback, minor revisions were made to wording and item difficulty to improve clarity and developmental appropriateness. Prior to the main study, the NAT was pilot-tested with 20 Grade II students from a different elementary school who were not included in the final sample. Item analysis was conducted to examine item difficulty and discrimination indices, resulting in the retention of all 30 items within acceptable ranges for elementary-level assessment.

The internal consistency reliability of the NAT was estimated using Cronbach's alpha, yielding $\alpha=0.82$, indicating good reliability for research purposes. This reliability level suggests that the NAT provides a consistent measurement of students' numeracy achievement across the assessed domains (Suyitno, 2021).

Data were analyzed using IBM SPSS Statistics version 26. Descriptive statistics, including means and standard deviations, were calculated for both pre-test and post-test scores. Data normality was assessed using the Kolmogorov–Smirnov test, and homogeneity of variances was assessed using Levene's test; both indicated that the assumptions for parametric analysis were met ($p > .05$). To evaluate within-group improvements, paired-samples t-tests compared pre-test and post-test results within each group. To examine between-group differences, independent-samples t-tests were used to compare the post-test means of the experimental and control groups (Pranata & Husain, 2022). The intervention's effect size was calculated using Cohen's d , with interpretation based on conventional benchmarks: 0.2 (small), 0.5 (medium), and 0.8 (large). All statistical tests were two-tailed with a significance level of $\alpha = 0.05$.

Based on the research objectives and the actual experimental pre-test–post-test control group design, the following hypotheses were formulated: (a) H_0 : *There is no significant difference in numeracy achievement between students who receive traditional game-based learning using Congklak and those who receive conventional textbook-based instruction.*, and (b) H_1 : *Students who receive traditional game-based learning using Congklak will demonstrate significantly higher numeracy achievement than those who receive conventional textbook-based instruction.*

3. Results

Prior to hypothesis testing, assumption checks were conducted to determine whether parametric statistical analyses were appropriate. The normality of numeracy score distributions was examined using the Kolmogorov–Smirnov test. The results indicated that pre-test and post-test scores in both the experimental and control groups did not deviate significantly from normality ($p > .05$).

The assumption of homogeneity of variances was assessed using Levene's test. The results showed no statistically significant differences in variance between the experimental and control groups for either pre-test scores ($F(1, 58) = 0.38, p = .540$) or post-test scores ($F(1, 58) = 0.42, p = .519$). These findings indicate that the assumption of equal variances was satisfied (Diana & Saputri, 2021; Hui & Mahmud, 2023).

Taken together, the results of the normality and homogeneity tests support the use of parametric t-tests for subsequent analyses. Detailed results of the assumption testing are presented in Table 2.

Table 2. Normality and homogeneity tests of numeracy scores

Group	Variable	Kolmogorov–Smirnov (Sig.)	Levene's F	Sig.	Interpretation
Experimental	Pretest	.086	0.38	.540	Normal & Homogeneous
Experimental	Posttest	.092	0.42	.519	Normal & Homogeneous
Control	Pretest	.078	–	–	Normal
Control	Posttest	.074	–	–	Normal

These findings indicate that the assumptions of normality and homogeneity are satisfied, allowing the use of t-tests for hypothesis verification. Descriptive results of students' numeracy achievement in both groups are presented in Table 3. The mean pretest scores of the experimental

($M = 58.20$, $SD = 7.61$) and control groups ($M = 57.93$, $SD = 8.04$) are statistically comparable, confirming equivalence at baseline. After the intervention, the experimental group achieves a substantially higher post-test mean ($M = 78.47$, $SD = 6.92$) than the control group ($M = 66.13$, $SD = 7.25$). Descriptive statistics of students' numeracy achievement for the experimental and control groups are presented in Table 3. Prior to the intervention, the mean pretest score of the experimental group ($M = 58.20$, $SD = 7.61$) is comparable to that of the control group ($M = 57.93$, $SD = 8.04$), indicating similar baseline numeracy performance between groups (Akman & Çakır, 2020; Gudadappanavar et al., 2021).

Following the four-week instructional period, both groups demonstrate higher mean post-test scores. The experimental group obtains a post-test mean score of $M = 78.47$ ($SD = 6.92$), while the control group obtains a post-test mean score of $M = 66.13$ ($SD = 7.25$). The mean gain score is 20.27 points for the experimental group and 8.20 points for the control group (Pranata, 2022).

Table 3. Descriptive statistics of pre-test and post-test numeracy scores

Group	N	Pretest Mean	SD	Posttest Mean	SD	Mean Gain
Experimental	30	58.20	7.61	78.47	6.92	20.27
Control	30	57.93	8.04	66.13	7.25	8.20

The descriptive statistics suggest that both groups improve following instruction, but the increase in the experimental group is more pronounced, indicating the potential effectiveness of *Congklak*-based learning. To examine changes in numeracy achievement within each group, paired-samples t-tests were conducted comparing pre-test and post-test scores for the experimental and control groups. The results are presented in Table 4.

The analysis indicates that students in the experimental group show a statistically significant increase in numeracy scores from pre-test to post-test, $t(29) = 11.29$, $p < .001$. Similarly, the control group demonstrates a statistically significant improvement over time, $t(29) = 5.64$, $p < .001$. These results indicate that both instructional approaches are associated with gains in numeracy achievement across the study period (Susanti, 2021).

Effect sizes are calculated using Cohen's d to estimate the magnitude of within-group changes. The experimental group shows a larger effect size ($d = 2.06$) compared to the control group ($d = 1.03$). These effect size estimates are reported descriptively and should be interpreted in light of the study's short intervention duration and classroom-based design.

Table 4. Paired samples t-test results for pre-test and post-test scores

Group	Mean Difference	SD	t	df	Sig. (2-tailed)	Cohen's d
Experimental	20.27	6.28	11.29	29	< .001	2.06 (large)
Control	8.20	6.03	5.64	29	< .001	1.03 (large)

The large effect size (Cohen's $d = 2.06$) in the experimental group indicates that *Congklak*-based learning exerts a powerful influence on students' numeracy development, nearly twice that observed in the control group. To examine differences in numeracy achievement between groups following the intervention, an independent-samples t-test was conducted on post-test scores. Prior to analysis, Levene's test indicates that the assumption of homogeneity of variances is met, $F(1, 58) = 0.42$, $p = .519$.

The results show a statistically significant difference in post-test numeracy scores between the experimental and control groups, $t(58) = 4.96$, $p < .001$. The experimental group's post-test score is

higher than the control group, with a mean difference of 12.33 points. The magnitude of the between-group difference is estimated using Cohen's *d*, yielding an effect size of $d = 1.27$.

These results indicate that, at the end of the instructional period, students in the experimental group achieve higher numeracy scores than students in the control group (Bang et al., 2022; Risdiyanti & Prahmana, 2020). The effect size is reported descriptively and should be interpreted with consideration of the classroom-based, cluster-assigned design and the limited duration of the intervention.

Table 5. Independent samples t-test for post-test scores

Variable	Levene's F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Cohen's d
Posttest score	0.42	.519	4.96	58	< .001	12.33	1.27 (large)

To further illustrate the intervention's magnitude, the gain scores (post-test minus pre-test) are analyzed. As shown in Table 6, the experimental group achieves a mean gain of 20.27 points compared with 8.20 points in the control group. An independent-samples t-test confirms that this difference is statistically significant ($t(58) = 6.78, p < .001$), reinforcing the conclusion that *Congklak*-based instruction leads to greater improvement in numeracy achievement.

Table 6. Independent samples t-test of gain scores

Group	N	Mean Gain	SD	t	df	Sig. (2-tailed)
Experimental	30	20.27	6.28	6.78	58	< .001
Control	30	8.20	6.03	–	–	–

The results of the statistical analyses indicate that both instructional conditions are associated with improvements in students' numeracy achievement over the study period. Paired-samples analyses show significant increases in pre-test-to-post-test scores for both the experimental and control groups ($p < .001$), suggesting that numeracy learning occurs under both instructional approaches.

However, the magnitude of improvement differed between groups. The experimental group achieves a higher mean gain score (20.27 points) than the control group (8.20 points). In addition, an independent-samples analysis reveals a statistically significant difference in post-test scores between the two groups ($p < .001$), with higher mean scores in the experimental condition. The corresponding effect size ($d = 1.27$) indicates a large difference between groups at post-test, given the study design and sample characteristics.

4. Discussion

The research purpose was to examine whether integrating traditional *Congklak*-based activities into mathematics instruction was associated with differences in numeracy achievement among Grade II elementary students when compared with conventional textbook-based instruction. The results indicate that students in both instructional conditions showed significant improvement in numeracy scores over the four-week period, while the experimental group demonstrated greater gains and higher post-test performance than the control group. This section discusses these findings in relation to existing theory and prior research, while also critically reflecting on methodological and contextual considerations (Khoiri et al., 2023; Lidinillah et al., 2022; Ramani et al., 2019).

The observed improvement in both groups suggests that structured mathematics instruction, regardless of instructional approach, contributes positively to students' numeracy development. This finding aligns with prior research indicating that systematic exposure to arithmetic practice and problem-solving activities supports early numeracy growth. However, the larger gains observed in the *Congklak*-based condition indicate that differences in instructional format may be associated with differences in learning outcomes at the conclusion of the intervention.

Rather than attributing these differences solely to the *Congklak* game itself, the findings should be understood as reflecting a combination of instructional features embedded in the intervention. These features include repeated numerical practice, active student engagement, opportunities for peer interaction, and the use of concrete materials (Chasanah et al., 2020; Pratama & Yelken, 2024; Suryadi et al., 2023; Thai et al., 2021). Based on this perspective, *Congklak* functioned as an instructional medium through which numeracy concepts were practiced in a structured yet interactive manner, rather than as an isolated causal factor.

Based on a cognitive-developmental perspective, the findings are consistent with theories emphasizing the role of concrete manipulation in early mathematical learning. According to Piagetian theory, children in the concrete operational stage benefit from learning activities that involve direct interaction with physical objects, as such experiences support the construction of numerical concepts (Yusuf, 2023). In the present study, distributing and counting *Congklak* seeds provided repeated opportunities for students to engage in one-to-one correspondence, sequencing, and simple operations, which may have supported the observed learning gains.

In addition, the collaborative nature of *Congklak*-based activities resonates with sociocultural perspectives on learning. Vygotskian theory emphasizes that cognitive development is mediated through social interaction and guided participation. During *Congklak* sessions, students interacted with peers, discussed strategies, and received feedback, which may have contributed to the development of mathematical reasoning through shared problem-solving experiences.

The findings also align with a broader body of international research on game-based and play-based learning in early mathematics. Studies on non-digital board games and number games in Western contexts have reported positive associations between structured gameplay and numeracy development, particularly for young learners (Hartanto et al., 2021; Sudarmin et al., 2023; Toheri et al., 2020). Research by Siegler and Ramani, for example, has shown that board games with numerical progression can support number sense and arithmetic understanding among primary-age children. By situating *Congklak* within this broader literature, the present study contributes a culturally specific example of how traditional, non-digital games may serve similar instructional functions across diverse educational contexts.

An essential aspect of the present study is its focus on a culturally familiar traditional game. The use of *Congklak* may have supported student engagement by connecting classroom learning with everyday cultural practices. However, increased engagement should not be interpreted as evidence that cultural relevance accounts for the observed outcomes (Setyowati et al., 2020; A. Wijaya et al., 2021). Engagement interacts with other instructional factors, such as time on task, clarity of learning objectives, and teacher guidance, all of which were structured within the intervention.

Instead of this standpoint, *Congklak*-based learning can be understood as a form of culturally responsive pedagogy that integrates local cultural resources into formal instruction without displacing curricular goals. This finding is consistent with research suggesting that culturally grounded instructional tools can enhance accessibility and participation, particularly in early education, when learners benefit from familiar and meaningful learning contexts (Murtagh et al., 2022; Yoda et al., 2024).

Despite the positive associations observed, several methodological considerations should be taken into account when interpreting the findings. First, group assignment was conducted at the class level rather than through individual randomization. Although baseline equivalence was established statistically, the possibility of clustering effects cannot be fully ruled out. Second, the study was conducted in a single school over a relatively short intervention period of four weeks (Aliriad et al., 2024; Khaleel et al., 2020; Pathuddin et al., 2021; Susanta et al., 2023). As a result, the generalizability of the findings to other settings, grade levels, or longer instructional durations remains limited.

Teacher-related factors also warrant consideration. Although the same teacher taught both groups and instructional guidelines were standardized, differences in teacher enthusiasm or classroom dynamics during *Congklak* sessions may have influenced student engagement (Shahbari & Daher, 2020; Siregar et al., 2020). In addition, the use of identical pre-test and post-test instruments, while controlled through item reordering, may have introduced some degree of test familiarity.

The large effect sizes observed in this study should therefore be interpreted with caution. While they indicate meaningful differences within the study context, replication across multiple schools, teachers, and longer time frames is necessary to determine the stability and scalability of the findings.

5. Conclusion and implications

This study examined differences in numeracy achievement between Grade II elementary students who received *Congklak*-based game learning and those who received conventional textbook-based instruction. The results indicate that both instructional approaches were associated with improvements in students' numeracy performance over the four-week period. However, students in the *Congklak*-based condition demonstrated higher post-test scores and larger gain scores than those in the conventional instruction condition, with a statistically significant between-group difference and a large effect size ($d = 1.27$).

These findings indicate that integrating structured *Congklak*-based activities into mathematics instruction may be associated with enhanced numeracy outcomes compared with textbook-based approaches alone. Rather than treating *Congklak* as a singular causal factor, the results should be interpreted as reflecting the combined influence of the instructional features embedded in the intervention, including concrete manipulatives, repeated numerical practice, guided peer interaction, and clearly defined learning objectives. Within this framework, *Congklak* functioned as a culturally familiar medium through which numeracy concepts were practiced in an interactive and contextually meaningful manner.

Based on a pedagogical perspective, the findings imply that traditional, non-digital games can be incorporated into early mathematics instruction as complementary learning resources, provided they are carefully structured and aligned with curricular goals. For classroom practice, *Congklak*-based activities can support counting, basic operations, and simple reasoning tasks, particularly in learning environments where engagement and access to learning materials are key considerations. Teachers are encouraged to integrate such activities with explicit instructional guidance, formative assessment, and classroom management strategies to ensure that play-based learning remains focused on intended learning outcomes.

In terms of broader implications, this study contributes to the literature on culturally responsive pedagogy by illustrating how local cultural practices can be integrated into formal educational settings without displacing academic standards. At the same time, the findings should be viewed as

context-specific and preliminary. Future research is needed to examine the robustness of these results across different schools, grade levels, and instructional durations, as well as to explore the applicability of similar game-based approaches to other areas of mathematics and learning domains. Such research would help clarify the conditions under which traditional games can be most effectively leveraged to support early numeracy development.

6. Limitation

Although this study provides strong evidence for the positive impact of *Congklak*-based learning on students' numeracy achievement, several limitations should be acknowledged. First, the sample was limited to 60 second-grade students from a single public elementary school in Yogyakarta, which may restrict the generalizability of the findings to broader populations or different educational settings. Second, the intervention lasted only 4 weeks; thus, the long-term retention of learning outcomes could not be assessed. Third, the study focused solely on basic arithmetic and simple problem-solving, leaving other aspects of numeracy, such as measurement, geometry, and data interpretation, unexplored. Additionally, classroom observations were limited to fidelity monitoring rather than qualitative analysis of student interactions, which could have provided richer insight into the learning dynamics. Future research should therefore include larger, more diverse samples, longer intervention periods, and mixed-methods approaches to better understand how traditional game-based learning influences the cognitive, social, and emotional aspects of mathematical development across various contexts.

Credit authorship contribution statement

Beti Istanti Suwandayani contributed to conceptualization, methodology, investigation, data curation, formal analysis, original draft writing, and supervision. Rivatul Ridho Elvierayani was involved in methodology, validation, and writing – review & editing. Lala Jelita Ananda contributed to investigation, data curation, and formal analysis. Erna Yayuk provided resources, project administration, and investigation. Dyah Worowirastri Ekowati contributed to validation and writing – review & editing. Trisniawati was responsible for visualization and writing – review & editing. Zulkifley Bin Mohamed contributed to conceptualization, methodology, and writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request. Because the data include human participant information, they are not publicly available to protect participant privacy.

Ethical Declaration

This study was conducted in accordance with ethical guidelines and did not undergo formal ethics committee review. The study involved the collection of data through pre-test and post-test assessments with elementary school students, and the research team determined that all procedures posed minimal risk to participants. The study adhered to the principles outlined in the Declaration of Helsinki. Verbal informed consent was obtained from all participants prior to their involvement in the study, including consent for the collection of data, use of responses, and observations for research purposes. Participation was voluntary, and participants had the right to withdraw from the study at any time without facing any consequences. To ensure

confidentiality, no personally identifiable information was collected. All data was anonymized at the point of collection, stored securely, and access to the data was limited to the research team.

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Declaration of AI statement

Declaration of generative AI and AI-assisted technologies in the writing process: During the preparation of this work, the author(s) used OpenAI ChatGPT version 5.2 to improve the clarity, academic tone, and readability of the manuscript. After using this tool/service, the author(s) reviewed and edited the content as needed and take full responsibility for the content of the published article. Generative AI was not used to generate research data, perform statistical analyses, or make decisions affecting the study's findings.

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