Differences in Numeracy Skills of Children Aged 5-6 Years Between Mathventure Games and Conventional Learning

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Abstract
This study aims to examine the influence of the Mathventure game on the numeracy skills of children aged 5-6 years in the domains of numbers, patterns, and spaces. This quantitative research used a quasi-experimental Nonequivalent Control Group Design with 40 children from two kindergartens in East Surabaya. Data were collected through structured observation using an observation instrument with a rating scale and analyzed descriptively and inferentially (Independent Sample T-Test/Mann-Whitney U). The posttest mean total score was 25.90 in the experimental group and 19.85 in the control group, with a very large effect size (Cohen's d = 2.81 for the total score and 1.41-1.82 across the three domains). These findings show that the Mathventure game has a significant impact on the skills of recognizing numbers, patterns, and spaces. This improvement is supported by tiered challenges and instant feedback in the form of animation and sound in the game; however, the contribution of these mechanisms was not tested separately. The limitations of the study include a small sample drawn from only two kindergartens in one region, short-term measurement without a retention test, confounding variables that were not deeply controlled (familiarity with digital devices and parental support), and observer subjectivity on the rating scale. Practically, these results encourage PAUD teachers to use educational digital games as an alternative numeracy medium, accompanied by adult assistance.

1. Introduction

Numeracy in early childhood refers to children's capacity to recognize, comprehend, and apply the concept of numbers and the relationships among them in everyday life. It is not limited to the ability to say numbers aloud, but also covers an understanding of numbers, comparisons, and number sequences. This capacity serves as an important foundation for children's later mathematical achievement (Gashaj et al., 2023), and a range of early number competencies has been shown to predict later mathematics achievement (Devlin, Jordan, & Klein, 2022). Between the ages of 5 and 6, children's numeracy begins to move from concrete toward symbolic understanding. Children are generally able to count objects, recognize number symbols, match numerals to the quantity of objects, and compare groups of objects in terms of many and few. They also begin to grasp the order of numbers and simple number relationships, which indicates that numeracy at this age already involves understanding the meaning of numbers rather than mere memorization (Chatzaki & Moeller, 2026; Liu & Zhang, 2022). Numeracy skills for children aged 5–6 years include counting in sequence, counting objects according to a given number, recognizing number symbols, and comparing the quantity of objects.

Children's numeracy develops from concrete to symbolic understanding. At this stage, children start to understand numbers, sequences, and number comparisons, so the number domain is no longer treated as memorizing numerals but as a conceptual understanding of quantity relations. Macdonald and Rafferty (2015) stress that early childhood numeracy involves developing the domains of number, patterns, and space, which are integrated into meaningful play experiences and investigations. The pattern domain helps children recognize order, repetition, and structure, while the spatial domain supports understanding of position, direction, shape, and the real forms found in their surroundings. Strengthening numeracy across these three domains also calls for contextual and gradual learning activities. Research on game-based interventions (Chatzaki & Moeller, 2026; Gasteiger & Moeller, 2021) reported that early numerical competence can be fostered through systematically designed activities, which in Chatzaki and Moeller (2026) were facilitated by an adult in small groups. Furthermore, mastery of the number, pattern, and space domains ultimately leads to functional numeracy skills. Ojose (2011) emphasizes that numeracy (mathematical literacy) involves not only mastering concepts but also being able to apply them meaningfully in daily life. The integration of the number, pattern, and

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space domains is therefore an important foundation for building applicative and contextual numeracy skills in early childhood.

International empirical evidence also illustrates the condition of early childhood numeracy. Early mathematical skills that are not mastered before school entry may cause difficulties in acquiring more complex mathematical skills, and when no specific intervention is given, individual differences present at school entry tend to remain stable or even widen over the following school years (Chatzaki & Moeller, 2026). Since early numeracy is the basis for later mathematical achievement (Gashaj et al., 2023), children who have not yet mastered basic skills such as counting and understanding cardinality need support before entering primary school. Low numeracy is not only reported in previous studies, but was also found by the researcher through field observations in various kindergartens in the eastern part of Surabaya. These observations showed that many children aged 5–6 years still have difficulty ordering the numbers 1–20 correctly. The most frequent problem is that children often become confused when recognizing number symbols with similar shapes, particularly 6 and 9, which is consistent with evidence that young children frequently produce mirror-reversed digits (Fischer, 2024). The low learning outcomes and the children's confusion occur because the learning methods used so far have not been engaging enough to help children understand basic mathematical concepts easily.

The limited variety of learning methods and media often makes the learning process monotonous and poorly matched to the characteristics of today's young children, who need engaging and interactive learning activities. Alternative approaches are therefore needed that actively involve children, one of which is digital games, provided the games are developmentally appropriate for young children (Crescenzi-lanna, 2022). Kiili (2005) explains that digital games can be an effective learning tool because children learn through hands-on play experiences. Children do not merely see or hear; they actively try, make mistakes, and correct them based on the responses the game provides. This process makes learning activities more meaningful and less boring. Digital games also contain several important elements. The goal of the game helps children understand what they need to do, such as recognizing numbers or matching the number of objects. Challenges are adjusted to the child's abilities so that they are neither too difficult nor too easy. Feedback is delivered immediately through visuals, sounds, or animations, so children can quickly see the results of their actions. These elements help children stay focused and interested in continuing to play and learn. Playing a digital game also proceeds gradually.

Based on the above, numeracy skills for children aged 5–6 years need to be developed through learning that suits the characteristics of children's development. Previous research findings and field observations show that children's numeracy skills are still not optimal because the learning methods used are not interesting enough and do not fully involve children. Learning media innovations that provide a fun and meaningful learning experience are therefore needed. The MathVenture game has the potential to serve as an alternative numeracy learning medium because it combines play activities, challenges, and direct feedback that can help children understand the concepts of numbers, patterns, and space. Accordingly, this study was conducted to examine the influence of using the MathVenture game on the numeracy skills of children aged 5–6 years.

Numeracy skills in children aged 5–6 years include the ability to understand numbers both symbolically and non-symbolically, such as counting objects, recognizing number symbols, and understanding number order and comparison as part of early numeracy development. At this stage, children can generally link number words to the quantity of objects and understand the cardinality principle, namely that the last number said when counting indicates the total number of objects (Chatzaki & Moeller, 2026). Besides number skills, numeracy at this age also includes recognizing patterns, grouping objects by certain characteristics, and understanding simple numbers that appear in daily play activities. found that kindergarten children's patterning skills explained additional variability in applied problem solving and arithmetic fluency one year later in Grade 1. Numeracy skills for children aged 5–6 years thus include understanding numbers, recognizing patterns, and grouping objects, which are related to other early cognitive skills and to activities that support the development of these abilities. Children of this age are also at the informal numeracy stage, in which they can count in sequence, recognize the properties of objects, and use numbers in simple contexts without high demands for abstraction. Numeracy development at this stage is more effective when carried out through meaningful play activities, because children learn by manipulating objects, trying things, and repeating experiences directly (Gasteiger & Moeller, 2021; Kiili, 2005). Numeracy skills for children aged 5–6 years therefore need to be understood as a comprehensive ability covering an understanding of numbers, patterns, and spatial relationships, which develops optimally through play experiences suited to children's developmental characteristics (Kiili, 2005). In short, numeracy at this age develops through the informal numeracy stage, which is effectively acquired through play activities involving numbers, patterns, and geometric shapes.

Digital games can be used in early childhood education because they can offer a meaningful play experience and support numeracy skills (Pan, Ke, & Xu, 2022). Mobile learning games have also been used to foster early mathematics among early primary-grade children from low-income backgrounds (Amorim et al., 2023). Game-based learning has been shown to support kindergarten children's early numerical development through

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concrete and contextual experiences (Chatzaki & Moeller, 2026), consistent with the view that numbers, patterns, and space are learned through meaningful play Macdonald and Rafferty (2015). Research by Chu, Paatsch, Kervin, and Edwards (2024) shows that educational digital games provide an interactive learning environment that encourages engagement, increases motivation, and supports gradual understanding of numeracy concepts. A systematic review of learning games in mathematics education also reported consistently positive effects of gameplay on mathematics learning performance, most often in arithmetic (Pan et al., 2022). Patterning is likewise an important part of early numeracy, because kindergarten children's patterning skills predict their later applied problem solving and arithmetic fluency (Di et al., 2022), and games can act as a dynamic platform that turns abstract mathematical knowledge into concrete visual representations (Pan et al., 2022). Research on number board games also shows that regular play can foster early numerical competencies, with more children advancing to higher levels of early mathematical development after playing the game than in a control group. Game-based media therefore have the potential to develop children's numeracy skills effectively through contextual play experiences, allowing children to learn to recognize and compare number symbols in a fun and easily understood way.

Besides numbers, object grouping, and patterns, the spatial domain is also important, because spatial skills and counting knowledge develop reciprocally in early childhood (Liu & Zhang, 2022). Numeracy media that involve the position of and relationships between objects on the screen can therefore support this domain. Spatial language and spatial knowledge are also related to kindergarten children's numeracy skills (Chan et al, 2025). Reviews of learning games further show that mathematical concepts can be embedded in gameplay through representations, prompts, scaffolds, and feedback (Pan et al., 2022). This approach aligns with the concept of playful pedagogies, which makes play the main vehicle for numeracy learning (MacDonald & Rafferty, 2015). Structured and challenging digital games can increase children's involvement in learning and create meaningful exploration experiences (Chu et al., 2024; Kiili 2005). Overall, digital games have the potential to be an effective learning medium for developing numeracy skills in children aged 5–6 years (Chatzaki & Moeller, 2026) with the in line with Ojose (2011), who argued that meaningful numeracy is built through the repeated application of the number, pattern, and space domains, all of which are relevant. However, reviews of mathematics learning games call for more research on game design and on how mathematical content is integrated into gameplay (Pan et al., 2022), and there is still little research on adventure-based digital games that integrate multiple numeracy domains holistically. Research on educational games such as MathVenture is therefore relevant for numeracy learning that is more contextual and suited to children's development. Digital games can be effective in developing numeracy skills in children aged 5–6 years, especially in numbers, patterns, and space, by providing a meaningful learning experience consistent with the playful pedagogies approach.

2. Method

This study uses a quantitative approach with a quasi-experimental design, namely Nonequivalent Control Group Design. This design was chosen to measure the influence of Game Mathventure on children's numeracy skills by comparing the group that was given treatment (experiment) and the group that was not (control) in the natural learning conditions in the classroom, a design that is commonly used in game-based learning research (Pan et al., 2022). This study involved 40 group B children aged 5–6 years from two kindergartens in the eastern region of Surabaya, selected through joint observation with the school based on the readiness of children's numeracy development, thus allowing in-depth observation of changes in children's abilities in a specific environment. Allocation to conditions was made at the school level rather than at the individual level: the experimental group (n = 20) came from the second kindergarten (School 2), and the control group (n = 20) came from the first kindergarten (School 1). Children were not randomly assigned, and the basis for deciding which group received the game was the guidance of the kindergartens, which was then confirmed with the supervising lecturer. The data collected were in the form of quantitative scores that represented children's numeracy skills. Primary data included pretest and posttest scores obtained from direct observation of children's ability to complete numeracy tasks. In addition, secondary data in the form of documentation of children's activities and works were collected to strengthen quantitative findings and provide physical evidence of children's development during treatment.

Data collection was carried out through structured observation using a rating scale instrument. The instrument indicators are specifically designed to measure three numeracy domains: (1) Numbers, including number recognition, counting the number of objects, and simple operations; (2) Patterns, including color pattern recognition, shape patterns, and object size sequencing; and (3) Space, including understanding the position and direction of objects. Each indicator is assessed based on the child's level of task completion and independence. Scoring followed a rubric in which each indicator was rated on a 1-4 scale, giving possible score ranges of 3–12 for Numbers, 3–12 for Patterns, 2–8 for Space, and 8–32 for the Total score. Observations were made by two observers, namely the researcher and the classroom teacher. The children were not aware of which group they had been assigned to. The data analysis technique uses descriptive and inferential statistics. Descriptive analysis is used to compare the average pretest and posttest scores, while inferential analysis begins with normality and homogeneity tests as a prerequisite test. If the data is normally distributed and homogeneous, an Independent Sample T-Test is carried out using SPSS to determine the significance of the difference in numeracy ability between the experimental and control groups, so that it can test the research

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hypothesis. The research procedure follows a systematic flow starting from initial observation and pretest, followed by the implementation of Mathventure game sessions in the experimental group and conventional learning in the control group, to posttest and data synthesis. The Mathventure intervention was delivered in 6 sessions over 6 weeks (once per week, 90 minutes per session), in an individual format. The control group received conventional worksheet-based learning for 6 sessions of 90 minutes each, the same as the experimental group. Before data collection, permission was obtained from the schools, which informed the children's parents/guardians, and the parents/guardians approved their children's participation. Participation was voluntary and free from coercion, and children or their parents/guardians could withdraw at any time without consequences. The children were informed in advance about the treatment. The menu display and game examples in each numbering domain (Numbers, Patterns, and Spaces) are presented in Figure 1.



Figure 1. Mathventure Game Main Menu Display with Three Numeracy Domains (Numbers, Patterns, Spaces)

This study used a quasi-experimental nonequivalent control group design with a pretest-posttest format, as shown in Table 1. Designs in which two groups are measured before and after a treatment have long been prominent in quantitative research. Both the Experiment group and the Control group took a pretest (O_1 and O_3) to measure their initial numeracy skills, received different treatments, and then took a posttest (O_2 and O_4). The Experiment group received the Mathventure Games intervention (X_1), while the Control group learned through conventional worksheets (X_2). The term "nonequivalent" means that participants were not randomly assigned to groups. This is common in school settings, where a small number of intact classes are typically allocated to planned learning conditions. Because such designs are vulnerable to loss of internal validity when groups differ at baseline, the pretest served as a baseline, and the initial group difference was reported descriptively rather than treated as proof of equivalence. The treatment effect was then evaluated by comparing the pretest-posttest results of the two groups (Lindstromberg, 2025).

Table 1. Research Design (Nonequivalent Control Group Design Notation)

Groups	Pretest	Treatment	Posttest
Experiments	O_1	X_1	O_2
Controls	O_3	X_2	O_4

3. Results and Discussion

The data analyzed included Pretest scores (O1 for the Experimental group and O3 for the Control group) taken before treatment, as well as Posttest scores (O2 for the Experimental group and O4 for the Control group) taken after the treatment. The Experimental group (n=20) received treatment in the form of the use of Mathventure Games, while the Control group (n=20) received learning using conventional learning media.

Table 2. Descriptive Statistics of Pretest and Posttest Scores

Phase	Domain	Groups	n	Mean	SD
Pretest	Numbers	Experiments	20	4.60	0.75
		Controls	20	4.85	1.39
	Pattern	Experiments	20	4.85	1.18
		Controls	20	5.55	1.19
	Space	Experiments	20	3.30	1.13
		Controls	20	3.35	0.81
	Total	Experiments	20	12.75	2.00
		Controls	20	13.75	1.92
Posttest	Numbers	Experiments	20	9.65	1.31
		Controls	20	7.95	1.10
	Pattern	Experiments	20	9.65	1.23

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Phase	Domain	Groups	n	Mean	SD
		Controls	20	7.25	1.41
	Space	Experiments	20	6.60	1.10
		Controls	20	4.65	1.46
	Total	Experiments	20	25.90	2.15
		Controls	20	19.85	2.16

Based on Table 2, the Pretest scores of the Experiment and Control groups were relatively equal across domains (Total: 12.75 vs. 13.75). In the Posttest, the average score of the Experiment group increased and exceeded the Control in all domains, with the largest difference in the Total score (25.90 vs. 19.85). The Control group's Pretest means were descriptively higher than those of the Experiment group in every domain and in the Total score (13.75 vs. 12.75), so the Posttest difference cannot be attributed to a head start of the Experiment group. Because the groups were not randomized, however, Posttest comparisons that do not adjust for Pretest scores should be read together with the N-Gain results below. A comparison of the average Pretest and Posttest scores is presented in Figure 2 and Figure 3.

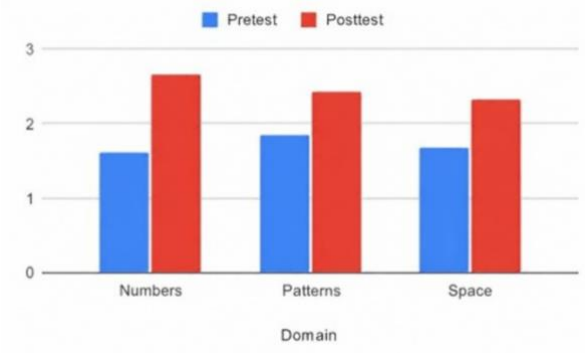


Figure 2. Comparison of Average Scores of Control Group

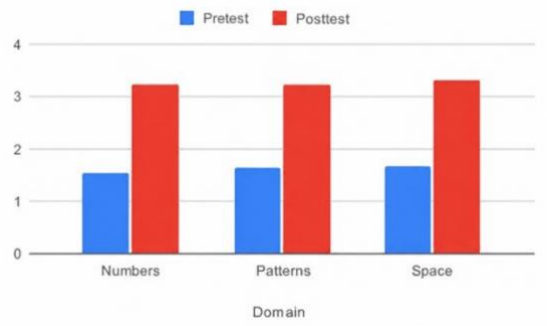


Figure 3. Comparison of Average Scores of Experimental Groups

3.1.1. N-Gain Score and Test Paired Sample

To see the amount of score increase from Pretest to Posttest in each group, the N-Gain Score was calculated (Hake, 1998). The calculation results are presented in Table 3. The N-Gain values of the two groups were compared using The N-Gain scores of the experimental and control groups were compared using an Independent Samples T-Test. The normality assumption was assessed using the Shapiro–Wilk test, while homogeneity of variance was examined using Levene's test. The N-Gain scores were normally distributed in both groups ($p > 0.05$), and the homogeneity of variance assumption was satisfied ($p = 0.811$). The Independent Samples T-Test revealed a statistically significant difference in N-Gain scores between the experimental and control groups, $t(38) = 8.923$, $p < 0.001$. The experimental group achieved a higher mean N-Gain score ($M = 0.678$, $SD = 0.125$) than the control group ($M = 0.330$, $SD = 0.121$), and the Sig. (p) column in Table 3 reports the result of this comparison.

Table 3. N-Gain Score of the Experimental and Control Groups

Domain	N-Gain Experiment	Categories	N-Gain Control	Categories	Sig. (p)
Numbers	0.680	Medium	0.408	Medium	<0.001
Pattern	0.661	Medium	0.246	Low	<0.001
Space	0.676	Medium	0.271	Low	<0.001
Total	0.678	Medium	0.330	Medium	<0.001

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Table 3 shows that the N-Gain of the Experimental group at the Total score (0.678) was in the medium category near high, while the Control group (0.330) was in the moderate category tending to be low. The difference in N-Gain between groups yielded a significance value of <0.001 (p<0.05) across the domain, indicating that the magnitude of the increase in the Experimental group was significantly higher than that of the Control group.

In addition, the Paired Sample test in each group showed that both the Experiment group (Paired T-Test, p<0.001) and the Control group (Paired T-Test, p<0.001) experienced a significant score increase from Pretest to Posttest. However, as shown by the N-Gain Score, the magnitude of the increase in the Experiment group was much greater than in the Control group.

3.1.2. Normality and Homogeneity Test

Before the hypothesis test was carried out, a prerequisite test was first carried out in the form of a Shapiro-Wilk normality test and a Levene homogeneity test. The results of the normality test showed that the Total score in the Pretest and Posttest was normally distributed in both groups (Sig.>0.05). Some scores per domain (especially the Number and Space domains) were not normally distributed, so different tests for these domains used

Mann-Whitney U Test, while Total score uses Independent Sample T-Test. The results of the normality and homogeneity test are presented in Table 4.

Table 4. Normality (Shapiro-Wilk) and Homogeneity (Levene) Test Results

Phase	Domain	Sig. SW-Eks	Sig. SW-Ktl	Norm.	Sig. Lev	Homog.
Pretest	Numbers	0.007	0.050	Abnormal	0.014	Not Homogeneous
	Pattern	0.090	0.300	Normal	0.677	Homogeneous
	Space	0.018	0.011	Abnormal	0.514	Homogeneous
	Total	0.169	0.645	Normal	1.000	Homogeneous
Posttest	Numbers	0.009	0.057	Abnormal	0.406	Homogeneous
	Pattern	0.022	0.035	Abnormal	0.445	Homogeneous
	Space	0.033	0.100	Abnormal	0.409	Homogeneous
	Total	0.107	0.533	Normal	0.910	Homogeneous

Based on Table 4, in the Pretest, the Pattern domain and Total score are normally distributed (Sig. > 0.05), while the Number and Space domains are not normally distributed (Sig. < 0.05). In the Posttest, only the Total score is normally distributed, while the Number, Pattern, and Space domains do not meet the assumption of normality. The abnormality suggests that the distribution of domain scores tends to be asymmetrical, likely due to the child's increased ability in the Experiment group being uneven and concentrated on a specific value, whereas the Total score has a more stable distribution because it is a composite score. The Levene test shows that the variance of the Experiment and Control groups is homogeneous (Sig. > 0.05) in almost all domains and phases, except for the Number domain in the Pretest (Sig. = 0.014). The results of these prerequisite tests are the basis for the selection of the analysis, namely the Independent Sample T-Test for the normally distributed Total score and the Mann-Whitney U Test for domains that do not meet the assumption of normality.

3.1.3. Hypothesis Test

Hypothesis testing was carried out to determine whether there was a significant difference between the Experimental and Control groups, both at the Pretest stage (to ensure initial equality of the two groups) and at the Posttest stage (to test the effectiveness of the treatment). The results of the hypothesis test are presented in Table 5.

Table 5. Hypothesis Test Results (Independent Sample T-Test / Mann-Whitney U)

Phase	Domain	Test Type	Statistics	Sig. (p)	Remarks
Pretest	Numbers	Mann-Whitney U	183	0.643	Insignificant
	Pattern	Independent T-Test	-1.866	0.070	Insignificant
	Space	Mann-Whitney U	182.5	0.628	Insignificant
	Total	Independent T-Test	-1.616	0.114	Insignificant
Posttest	Numbers	Mann-Whitney U	331.5	<0.001	Significant
	Pattern	Mann-Whitney U	357.5	<0.001	Significant
	Space	Mann-Whitney U	342.5	<0.001	Significant
	Total	Independent T-Test	8.881	<0.001	Significant

The results of the hypothesis test in the Pretest stage showed a significance value greater than 0.05 across all domains and Total scores, meaning that there was no significant difference between the Experimental and Control groups before being given the treatment. These findings confirm that the two groups were in equal initial

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conditions, thus meeting important prerequisites for the validity of the quasi-experimental research design (Nonequivalent Control Group Design).

On the other hand, the results of the hypothesis test at the Posttest stage showed a significance value of less than 0.05 in all domains and the Total score ($p<0.001$ for the Total score, $t=8.881$). This proves that after the treatment, there was a significant difference between the Experiment and Control groups, with the Experimental group showing higher achievement of numeracy skills in all domains (numbers, patterns, and spaces). Thus, the research hypothesis that Mathventure Games have a significant effect on the numeracy skills of children aged 5–6 years is acceptable. Because several comparisons were made (four at the Pretest and four at the Posttest in Table 5, and four N-Gain comparisons in Table 3), the risk of false-positive findings was considered. Using a Bonferroni-adjusted threshold of $0.05/4 = 0.0125$ for the four Posttest comparisons, all Posttest p values (<0.001) remain significant, whereas none of the Pretest comparisons reached significance even at the unadjusted level of 0.05. Non-significant Pretest results are interpreted only as the absence of a detectable difference, not as proof of equivalence between the groups.

3.1.4. Effect Size (Cohen's D)

To determine the practical magnitude of the effect of the treatment (not just statistical significance), the value of Cohen's Effect Size d was calculated at the Posttest stage (Cohen,1988). The results of the calculation are presented in Table 6.

Table 6. Effect Size (Cohen's D) Experimental Vs Control Posttest

Domain	Cohen's d (Posttest)	Categories
Numbers	1.407	Large
Pattern	1.817	Large
Space	1.510	Large
Total	2.808	Large

Table 6 shows that all domains have an effect size in the large category ($d>0.8$), with a total score of $d=2.81$ which is classified as very large. These findings confirm that the influence of Mathventure Games on children's numeracy skills is not only statistically significant, but also large in practical terms.

3.2. Discussion

The results of the study show that the Mathventure Game has a significant and substantive effect on the numeracy skills of children aged 5–6 years in the domains of numbers, patterns, and spaces. These findings strengthen the view of Macdonald and Rafferty (2015) that early childhood numeracy encompasses all three domains that are interintegrated in the experience of meaningful play and investigation, and Mathventure has proven to be able to stimulate them simultaneously.

In the Number domain, the Experiment group increased more than the Control group (Posttest 9.65; SD=1.31 vs 7.95; SD=1.10; N-Gain 0.680; Cohen's d=1.407, large category). These findings are in line with Pan et al. (2022), who reported consistently positive effects of math learning games on students' mathematics learning performance. However, the evidence regarding the advantages of digital games is not entirely uniform. Barrocas, Bahnmueller et al, (2023) found that a short-term, game-like math app for kindergarten children did not significantly improve math skills compared with a content-matched unplugged training program or a waiting-list control group. also concluded that evidence on whether individual differences, such as prior mathematics knowledge, moderate the effects of game play remains inconclusive. Thus, the advantage of Mathventure is more accurately interpreted as an advantage over static worksheets, rather than over all forms of learning. This advantage may come from repeated experiences and instant feedback in the form of animations and sounds that help children correct mistakes immediately, in line with (Ojose, 2011), who argued that meaningful numeracy is built through the repeated application of concepts in varied contexts, not the memorization of symbols. Such feedback may be particularly useful for visually similar numerals such as 6 and 9, which young children often confuse or write in reversed form (Fischer, 2024).

The Pattern domain showed the most notable improvement ($d=1.817$; highest). The Experiment score rose from a Pretest of 4.85 to a Posttest of 9.65, while a Control N-Gain of only 0.246 (low). This is consistent with (Di et al., 2022), who found that patterning skills predicted later applied problem solving and arithmetic fluency, as well as with Macdonald and Rafferty (2015) who explained that patterns help children recognize order, repetition, and structure. Color, shape, and size sequencing in Mathventure seems to be more effective than pattern exercises on static two-dimensional worksheets,Preschool children's attention to pattern structure can be strengthened through suitable tasks and resources (Wijns et al., 2021). Patterns are also relatively independent of verbal numeracy skills, so children can build structural understanding through interactive visual manipulation without being burdened by symbols (Zhang et al., 2025).

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In the Space domain, the Experiment group also significantly improved in understanding the position and direction of objects, which is relevant because spatial skills and counting knowledge are reciprocally related in early childhood (Liu & Zhang, 2022). The Posttest score of this domain is the lowest in absolute terms (Experiment=6.60; Control=4.65), which may reflect that spatial skills are still developing together with counting knowledge during early childhood (Liu & Zhang, 2022). However, the Experimental N-Gain (0.676; medium) far exceeds the Control (0.271; low) with d=1.510 (large), in line with the view of Pan et al., (2022) that games can turn abstract mathematical knowledge into concrete visual representations, which may provide a more concrete spatial experience than worksheets (Chan et al., 2025).

Overall, the large effect size on all domains (very large on the Total score) showed a substantive practical impact, in line with Chu et al., (2024) who reported that educational digital games provide an interactive environment that gradually increases engagement, motivation, and numeracy understanding. The Control Group also increased significantly (Paired Sample), but its N-Gain was still moderate at Number (0.408) and low at Pattern (0.246) and Space (0.271). The Control group, which received conventional learning, also improved significantly, with a medium N-Gain in the Number domain (0.408) but low N-Gain in the Pattern (0.246) and Space (0.271) domains. This may suggest that conventional media are relatively adequate for symbol recognition and simple operations, but less able to support patterns and spatial relations, which benefit from attention to structure and dynamic manipulation of object (Acosta et al., 2026; Wijns et al., 2021). Media selection should therefore be matched to the numeracy domain being targeted, although this interpretation requires confirmation because the present design did not examine how each medium was used.

These findings are also in line with the experiential gaming model of Kiili (2005), in which a structured and challenging gaming experience increases engagement, as well as with Chatzaki and Moeller (2026), who reported more progression in early mathematical development among kindergarten children aged about 6 years who played a number board game than among control children. These results relate to the problem raised in the Introduction: early mathematical skills not yet mastered at school entry tend to persist or widen over time. In this context, structured digital play interventions may offer a promising approach. However, the outcomes observed may differ across students because of variation in teachers, schools, the level of guidance children received, and the amount of time spent practicing.. More broadly, these results are consistent with systematic reviews of digital play in the early years (Chu et al., 2024) and of learning games in mathematics education (Pan et al., 2022).

3.3. Limitations

Several limitations should be considered when interpreting these findings. First, the advantage of Mathventure is interpreted as an advantage over static worksheets rather than over all forms of learning, and the present design did not examine how each medium was used. Second, if each condition was represented by only one school, school characteristics are confounded with the treatment, so the observed differences cannot be attributed to Mathventure alone. Third, differences in teachers, in the assistance provided to children, and in the amount of practice time between the two conditions may also have contributed to the results. The repeated experiences and instant feedback offered by the game, which are proposed here as possible explanations, were not tested separately from these factors. Fourth, the domains may differ in score range, so absolute posttest scores are not compared across domains; comparisons across domains rely on relative indicators, namely N-Gain and Cohen's d. Finally, the study shows that the Experiment group outperformed the Control group under the conditions studied, and it does not establish that Mathventure resolves low numeracy caused by conventional methods.

3.4. Implications

The findings suggest that teachers and early childhood practitioners may consider Mathventure as an alternative to static worksheets, particularly for patterns and spatial relations, where the Control group gained the least. Media selection should be matched to the numeracy domain being targeted, although this interpretation requires confirmation. Adoption in classrooms is likely to depend on support for teachers, since a positive user experience with a curriculum guide has been shown to increase teachers' self-efficacy, which in turn enhances their acceptance of educational games (Sharma et al, 2025). A guide accompanying Mathventure would therefore be a practical way to support its use. For future implementation and research, each condition should be represented by more than one school, and teachers, assistance, and practice time should be documented or equalized so that the effect of the game can be separated from these factors. Reporting the score range of each domain would also allow readers to interpret absolute scores across domains.

4. Conclusion

This study aims to examine the effect of Mathventure Games on the numeracy skills of children aged 5-6 years in the domains of numbers, patterns, and spaces. The results show that the use of Mathventure Games has a significant and substantive effect: the posttest scores of the Experiment group were much higher than those of the Control group, which used conventional worksheets, with effect sizes (Cohen's d) in the large to very large range across all domains and the strongest influence on the Total score (d = 2.81). This finding responds to the

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problem raised in the Introduction, namely the low numeracy skills of early childhood due to conventional methods that are less engaging and involve children less actively, and it shows that digital game media that holistically integrates the three domains provides a more meaningful and effective learning experience. This study nevertheless has several limitations. First, the sample is relatively small (n = 20 per group) and was drawn from only 2 kindergartens in the East Surabaya area, so generalizations to the wider population should be made carefully. Second, the impact was measured only in the short term, so skill retention cannot yet be explained. Third, other variables with the potential to influence the outcomes were not controlled in depth, such as children's familiarity with digital devices, parental support at home that shapes children's numeracy experiences (Schnieders & Schuh, 2022), and individual learning styles. Fourth, although the rating-scale observation instruments are structured, they still carry a risk of observer subjectivity. Practically, the results encourage teachers and early childhood education practitioners to consider educational digital games such as Mathventure Games as a numeracy medium that is more interesting, interactive, and appropriate to children's developmental characteristics, without neglecting adult assistance, since adult-child co-use of digital media can support children's learning (Taylor et al., 2024). Theoretically, this study strengthens the body of research on the effectiveness of game-based learning and playful pedagogies in early childhood numeracy, especially in approaches that integrate multiple numeracy domains in a single medium. Future studies are suggested to examine long-term retention, involve more than one early childhood education institution with a more diverse population, control relevant confounding variables, and explore integration with other digital or hybrid approaches.

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Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethics and Consent Declarations

This study adhered to research ethics, particularly because it involved young children (aged 5-6 years). Prior to implementation, the researcher obtained permission from the school to respect the rights and welfare of the participating children. All data were used solely for academic purposes and kept confidential, and children's identities were protected through codes or initials. Participation was voluntary and free from coercion, and children or their parents/guardians could withdraw at any time without consequences. The MathVenture educational game was developmentally appropriate and harmless, with its duration and content following recommendations for gadget use in early childhood. The study also upheld academic integrity by avoiding plagiarism, data manipulation, and fraud, so that the results are scientifically accountable.

Data Availability

The datasets generated during and/or analyzed during the current study (anonymized pretest and posttest numeracy scores) are available from the corresponding author on reasonable request. The data are not publicly deposited in order to protect the privacy of the child participants.

Declaration on AI Use

The authors used AI-assisted tools only to improve the readability and language of this manuscript, under strict human oversight.

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