Shodh Sari-An International Multidisciplinary Journal

@2026 International Council for Education Research and Training
ISSN: 2959-1376
2026, Vol. 05, Issue 01, 174-203
DOI: https://doi.org/10.59231/SARI7897

Play and Creativity in Early Mathematics: Evidence from Pre-Primary Pupils in Nigeria

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Abstract

Persistent underachievement in mathematics remains a concern in Nigerian schools despite repeated curricular reforms, with little empirical research addressing instructional practices at the pre-primary level. This study investigated the effectiveness of play-based instruction in improving mathematics achievement and interest among Early Child Care Development III pupils in Enugu East Local Government Area. A quasi-experimental pre-test–post-test control group design was adopted using 51 pupils from two intact classes. The experimental group ($n = 26$) received instruction through card games, while the control group ($n = 25$) was taught addition of whole numbers (sums ≤ 10) using conventional counting strategies over a one-week period. Data were collected with the Number and Numeration Achievement Test (NNAT; $\alpha = .91$) and the Number and Numeration Interest Scale (NNIS; $\alpha = .95$). A Multivariate Analysis of Covariance (MANCOVA), with pre-test scores as covariates, revealed significant effects of instructional method on both achievement, $F(1, 47) = 136.72$, $p < .001$, $\eta^2 = .74$, and interest, $F(1, 47) = 142.55$, $p < .001$, $\eta^2 = .75$. These findings provide robust evidence that play-based approaches significantly enhance mathematics performance and engagement in early childhood. The study highlights the importance of integrating structured play into Nigerian early childhood mathematics curricula and calls for further research on long-term retention and scalability across diverse contexts.

Keywords: play-based instruction; mathematics achievement; learner interest; early childhood education; quasi-experimental design; Nigeria

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Introduction

Mathematical competence serves as a cornerstone of scientific advancement, technological progress, and economic development across nations. The foundational concepts acquired during early childhood—particularly number sense and basic operations establish cognitive frameworks that support subsequent learning across academic disciplines (Haruna & Daya, 2018; Onah, 2018). Yet despite its recognized importance, mathematics instruction in Nigeria continues to yield persistently poor outcomes. Recent examination data from the West African Examinations Council reveal that fewer than 25% of secondary school candidates achieve credit-level performance in mathematics (WAEC, 2018), signaling systemic inadequacies in pedagogical practices and curriculum implementation.

These challenges manifest with intensity at the pre-primary level, where young children's developmental characteristics including limited sustained attention and emerging abstract reasoning capacities complicate traditional instructional approaches. Nigeria's National Policy on Education explicitly advocates for play-based pedagogies in early childhood settings, positioning inquiry, creativity, and experiential exploration as central to quality ECCD provision (Federal Republic of Nigeria, 2014). However, empirical evidence suggests considerable divergence between policy aspirations and classroom realities. Many pre-primary teachers continue to employ didactic, teacher-centered methods that prioritize procedural memorization over conceptual understanding (Fisayo, 2018; Udegbe, 2024). Such approaches risk disengaging young learners during the critical period when mathematical foundations are established, potentially contributing to the negative attitudes and poor performance evident in later schooling.

A substantial body of theoretical and empirical scholarship supports the integration of play-based strategies into early mathematics instruction. Pedagogical approaches that embed mathematical concepts within games, manipulatives, and problem-solving activities align with children's natural propensity for exploration and discovery (Louw & Claassens, 2025; Palmér & van Bommel, 2018). These

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ISSN: 2959-1376
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methods operationalize constructivist learning principles articulated by Piaget, who demonstrated that cognitive development proceeds through active manipulation of concrete materials rather than passive reception of abstract information (Piaget, 1952). Similarly, Dienes' staged model of mathematical learning illustrates how structured play activities serve as bridges between informal intuitions and formal symbolic reasoning (Dienes, 1960).

Recent empirical investigations provide encouraging evidence for play-based pedagogies. Studies conducted in diverse international contexts document positive effects of playful mathematics instruction on both achievement outcomes and affective dispositions (Cohrssen, Church, & Tayler, 2016; Elaine, Sawalma, & Martin, 2022). Reikerås (2020) demonstrated significant associations between play skills and mathematical competencies among toddlers, while Shodiq, Juniati, and Susanah (2025) found that creativity-oriented problem-solving activities enhanced lateral thinking capacities. Within Nigerian contexts specifically, Udegbe (2024) reported superior achievement among primary pupils taught through play-based methods compared with traditional instruction, and Kwabe, Hannatu, & Waviche (2024) documented similar advantages for game-based science instruction. Ossai (2023) similarly found that guided play enhanced learning outcomes in Enugu State primary schools.

Despite accumulating evidence supporting play-based approaches at primary and secondary levels (Ezeugwu et al., 2016), research examining their effectiveness specifically within Nigerian pre-primary contexts remains limited. Taiwo (2023) advocates for play-based mathematics in early childhood education but notes the scarcity of rigorous experimental studies. The gap is particularly pronounced in Enugu State, where no published investigations have examined play-based interventions with ECCD III populations. This absence of localized evidence constrains informed decision-making by teachers, administrators, and policymakers regarding optimal instructional strategies during this foundational period.

Mathematical underachievement in Nigeria spans all educational levels, reflecting multifaceted challenges including ineffective pedagogical practices, insufficient teacher preparation, inadequate instructional

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resources, and negative learner attitudes (WAEC, 2018). Emerging research suggests that play-based instructional strategies may mitigate some of these challenges by increasing engagement, reducing mathematics anxiety, and supporting conceptual understanding (Cohrssen et al., 2016; Louw & Claassens, 2025). However, empirical evidence examining the effectiveness of such approaches within Nigerian pre-primary contexts particularly in Enugu East Local Government Area remains sparse.

This evidentiary gap presents practical challenges for educational stakeholders. Without rigorous local research, teachers lack empirical guidance regarding whether and how to implement play-based strategies. Administrators cannot make evidence-informed resource allocation decisions. Curriculum developers lack contextually grounded data to support policy recommendations. The fundamental question persists: Can play-based instructional approaches enhance both achievement and interest among ECCD III pupils in Enugu East, thereby establishing stronger mathematical foundations during this critical developmental period?

This study addresses this gap by examining the effects of play-based strategies on pre-primary pupils' mathematics achievement and interest in addition concepts. By providing empirical evidence from Nigerian public-school contexts, the investigation aims to inform pedagogical decision-making and contribute to discussions regarding optimal early childhood mathematics instruction.

Significance of the Study

This study has both theoretical and practical relevance. Theoretically, it provides empirical support for Dienes' six-stage theory of mathematics learning and Piaget's constructivist framework, both of which emphasize active, hands-on engagement.

Practically, the study is expected to:

- Assist pupils in building stronger foundations in numeracy while reducing mathematics-related anxiety.
- Guide teachers in adopting engaging methods that simplify lesson preparation and increase classroom participation.
- Relieve parents of the burden of paying for remedial lessons by promoting early mastery.
- Inform curriculum planners and policymakers about effective strategies that

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can be integrated into early childhood curricula.

- Contribute to societal development by nurturing mathematically literate learners who can contribute to national growth.

Purpose of the Study

This study examined the effects of play-based strategies on ECCD III pupils' mathematics achievement and interest in Enugu East Local Government Area, Nigeria. The study specifically aims to:

1. Compare the mean achievement scores of pupils taught addition with play-based strategies and those taught with conventional methods.
2. Compare the mean interest ratings of pupils exposed to play-based strategies and those taught with conventional methods.

Research Questions

1. What are the mean achievement scores of pupils taught mathematics addition using play-based strategies compared with those taught with conventional methods?
2. What are the mean interest ratings of pupils taught mathematics addition using play-based strategies compared with those taught with conventional methods?

Hypotheses

- H_{01}: There is no significant difference in achievement between pupils taught mathematics addition with play-based strategies and those taught with conventional methods.
- H_{02}: There is no significant difference in interest between pupils taught mathematics addition with play-based strategies and those taught with conventional methods.

Scope of the Study

The study is delimited to ECCD III (ages 4–5) pupils in Enugu East Local Government Area, Enugu State. The content scope is restricted to addition of numbers without carrying.

Theoretical Framework

This study integrates two foundational theories of childhood learning to examine play-based mathematics instruction: Piaget's constructivist developmental theory and Dienes' mathematical learning framework.

Piaget's Constructivist Foundations

Piaget's theory emphasizes that children actively build knowledge through interaction with their environment rather than absorbing information passively (Piaget, 1952, 1964). During the preoperational stage (ages 2-7), which encompasses ECCD III learners, cognition is characterized by concrete

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ISSN: 2959-1376 DOI: https://doi.org/10.59231/SARI7897

thinking and reliance on perceptual information. Piaget argued that mathematical understanding develops as children physically manipulate materials, observe relationships, and construct mental representations of numerical concepts. This developmental perspective suggests that effective early mathematics instruction should emphasize hands-on exploration and discovery-oriented problem-solving rather than abstract symbol manipulation or procedural memorization. Play-based approaches align with this theory by providing concrete, experiential contexts for mathematical learning.

Dienes' Learning Progression

Dienes (1960, 1971) proposed that mathematical understanding develops through six sequential stages: free play, structured games, identification of commonalities, representation, symbolization, and formalization. This framework suggests that abstract mathematical concepts become accessible when children first encounter them through concrete, game-based activities (Dienes & Golding, 1971). For example, addition concepts can be developed through games involving physical objects, where children experience combining quantities before working with written numerals. Dienes emphasized that structured play provides repeated, varied experiences that support pattern recognition and conceptual insight, serving as cognitive bridges between intuitive understanding and formal mathematics.

Theoretical Expectations

Both theories suggest that developmentally appropriate instruction characterized by concrete materials, meaningful contexts, and active problem-solving should enhance learning outcomes for young children. The present study tests whether play-based instruction, which embodies these theoretical principles, produces superior achievement and interest compared with conventional teacher-directed methods. If Piaget's and Dienes' propositions hold, experimental group pupils should demonstrate both stronger mathematical performance and greater engagement, as the instructional approach matches their cognitive capabilities and natural learning tendencies.

Method

Research Design

The study employed a quasi-experimental pre-test–post-test control group design. This

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design was suitable because intact classes were used, and random assignment of individual pupils was not feasible. The design allowed for the comparison of pupils taught mathematics addition with play-based and creative strategies (experimental group) and those taught through conventional methods (control group).

Population of the Study

The population consisted of all pupils in Early Child Care Development III (ECCD III) across public pre-primary and primary schools in Enugu East Local Government Area.

Sample and Sampling Procedure

The study involved 51 pupils enrolled in Early Child Care Development (ECCD) III classes from two public primary schools located in Enugu East Local Government Area of Enugu State. The schools were purposefully selected to ensure institutional comparability based on several criteria: public ownership, urban setting, mixed socioeconomic composition of the pupil population, teacher qualifications, class size, and physical learning environment.

School Selection Procedures

An official list of public primary schools offering pre-primary education in Enugu East (N = 14) was obtained from the Local Government Education Authority. Eligibility screening was guided by the following conditions: (a) enrollment of at least one ECCD III class with 20–30 pupils, (b) employment of teachers with the Nigeria Certificate in Education (NCE) specializing in Early Childhood Education, (c) availability of adequately equipped classrooms with basic instructional resources, and (d) willingness of school administrators to permit participation. Eight schools satisfied these requirements. From this pool, two schools showing close similarity in structure and operation were randomly chosen through a simple lottery procedure.

Within each participating school, one intact ECCD III class was selected in consultation with the head teacher to ensure timetable convenience and teacher availability. The first selected school served as the experimental site (n = 26), while the second served as the control site (n = 25). Although random assignment of schools to treatment conditions was not feasible due to administrative and logistical limitations, the use of separate institutions for each condition

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reduced the likelihood of contamination or information exchange between groups.

Participant Characteristics

The sample comprised 51 ECCD III pupils (27 males, 24 females) with ages ranging from 4.0 to 5.9 years (M=4.90, SD=0.50). Table 1 presents demographic characteristics by group.

Table 1: Demographic Characteristics of Participants by Group

Characteristic	Experimental (n=26)	Control (n=25)	Total (N=51)	p
Gender, n (%)				.671
Male	13 (50.0%)	14 (56.0%)	27 (52.9%)	
Female	13 (50.0%)	11 (44.0%)	24 (47.1%)	
Age in years				
M (SD)	4.88 (0.52)	4.92 (0.49)	4.90 (0.50)	.774
Range	4.0–5.8	4.1–5.9	4.0–5.9	
Prior ECCD, n (%)				.554
Completed I & II	24 (92.3%)	24 (96.0%)	48 (94.1%)	
Direct entry	2 (7.7%)	1 (4.0%)	3 (5.9%)	

Note. Chi-square tests and independent t-test revealed no significant baseline differences (all $p>.05$).

The experimental group consisted of 13 males (50.0%) and 13 females (50.0%) with mean age 4.88 years (SD=0.52), while the control group included 14 males (56.0%) and 11 females (44.0%) with mean age 4.92 years (SD=0.49). Groups did not differ significantly in gender distribution, χ^2 (1) =0.18, p=.671, age, t (49) =0.29, p=.774, or prior ECCD completion, χ^2 (1) =0.35, p=.554. This demographic equivalence, combined with non-significant pre-test differences, confirms that pupils from the two schools were well-matched at baseline.

School and Classroom Context

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The study was conducted in two public primary schools within Enugu East Local Government Area that offered pre-primary education and shared similar institutional features. School A, designated as the experimental site, had an enrollment of about 420 pupils, from which one ECCD III class comprising 26 pupils was selected. School B, assigned as the control site, enrolled approximately 360 pupils, with one ECCD III class of 25 pupils chosen for participation.

Both schools served urban communities with mixed socioeconomic backgrounds and exhibited comparable learning environments. They operated under public management, maintained similar class sizes, and employed teachers holding the Nigeria Certificate in Education (NCE) in Early Childhood Education with between seven and nine years of professional experience. The physical classroom conditions were also equivalent, featuring rooms measuring roughly 6 by 8 meters, furnished with adequate lighting, ventilation, seating, and standard instructional resources.

Regular teachers in both schools had taught their respective classes throughout the first term, ensuring comparable instructional exposure before the study commenced. During the intervention, the researcher personally conducted all mathematics lessons in both schools, while the classroom teachers observed to maintain uniformity in procedure. The use of two separate schools was intended to minimize contamination and prevent any exchange of instructional materials or experiences between the groups.

Statistical Power

Post-hoc power analysis using G*Power 3.1.9.7 indicated that with N=51, two dependent variables, two covariates, α=.05, and the observed effect size (f^2=3.00, derived from η^2=.75), statistical power exceeded .99. Even for detecting medium effect sizes (f^2=0.15), the study achieved power of .73. While the sample size was modest, it provided adequate power for detecting meaningful treatment effects.

Method of Data Analysis

Descriptive statistics (mean and standard deviation) were used to summarize pupils' scores in achievement and interest. To test the hypotheses, a Multivariate Analysis of Covariance (MANCOVA) was performed in R, with post-test scores in achievement and interest as dependent variables, instructional method as the independent variable, and pre-test scores as covariates. MANCOVA was

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considered appropriate because it allowed for the simultaneous examination of differences across the two outcome variables while controlling for initial group differences. The level of statistical significance was set at 0.05.

Instruments for Data Collection

Two instruments were developed specifically for this study: the Number and Numeration Achievement Test (NNAT) and the Number and Numeration Interest Scale (NNIS).

Number and Numeration Achievement Test (NNAT). The NNAT was designed to measure pupils' ability to solve simple addition problems involving whole numbers with sums not exceeding 10. The instrument consisted of fifteen items presented in both pre-test and post-test formats. Items required pupils to add three single-digit numbers (e.g., 1 + 1 + 2 = ___). This format was chosen to assess both computational accuracy and ability to hold multiple addends in working memory—a key component of early mathematical competence (Geary, 2011).

Each item was scored dichotomously (correct/incorrect), with each correct response worth 20 points, yielding a maximum score of 100 points. This scaling facilitated interpretation and comparison across groups. Although pre-test and post-test versions used different item combinations to prevent practice effects, both versions maintained equivalent difficulty levels through careful item selection. All items used addends from the set {1, 2, 3} and sums ranging from 3 to 6, ensuring content parallelism. Table 2 illustrates sample items from the NNAT.

Table 2: Sample Items from the Number and Numeration Achievement Test (NNAT)

Item No.	*Pre-Test Item*	*Post-Test Item*	*Correct Answer*
1	*1 + 1 + 2 = ?*	*2 + 1 + 1 = ?*	*4*
2	*1 + 1 + 1 = ?*	*1 + 1 + 1 = ?*	*3*
3	*2 + 1 + 3 = ?*	*1 + 3 + 2 = ?*	*6*
4	*1 + 3 + 1 = ?*	*1 + 1 + 3 = ?*	*5*
5	*2 + 2 + 1 = ?*	*1 + 2 +1=?*	*5*

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6.	*1 + 3 + 2 = ?*	*1 + 2 + 3 = ?*	*6*
7.	*2 + 1 + 1 =?*	*1 + 1 + 2 =?*	*5*
8.	*3 + 1 + 1 = ?*	*1 + 3 + 1 =?*	*5*
9.	*2 + 1 + 3 = ?*	*1 + 2 + 3 =?*	*6*
10.	*3 + 2 + 1 =?*	*2 + 3 + 1 =?*	*6*
11. 1	*+ 1 + 3 =?*	*1 + 3 * 1 =?*	*5*
12.	*2 + 1 + 1 =?*	*1 + 1 + 2=?*	*4*
13.	*3 + 2 + 1=?*	*2 + 1 + 3=?*	*6*
14.	*1 + 3 +2=?*	*3 + 1 +2=?*	*6*
15.	*2 * 2 +1*	*2 +1 + 2=?*	*6*

Note. Items assessed addition of three single-digit numbers without carrying. Cronbach's α = .91 for the five-item scale.

Number and Numeration Interest Scale (NNIS). The NNIS was developed to assess pupils' affective responses to mathematics instruction. The scale consisted of 15 statements designed to capture enjoyment, engagement, and desire for continued mathematics learning. Items were worded in age-appropriate language and administered orally to accommodate limited reading ability. Examples include "I enjoyed the class" and "I want us to continue with the class."

Because the participants were very young (ages 4–5) and possessed limited literacy skills, all instruments were administered orally through one-on-one sessions. The researcher read each question aloud in English and then translated it into Igbo language to ensure full comprehension, as Igbo was the dominant home language for most pupils in the sample (approximately 83.5%). Pupils gave verbal responses, which the researcher recorded immediately on the scoring sheets.

During the administration of the Number and Numeration Achievement Test (NNAT), pupils were shown concrete objects to visually represent numbers and support their understanding of addition tasks. For the Number and Numeration Interest Scale

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(NNIS), the four-point response options were explained using age-appropriate Igbo translations: *Strongly Disagree* ("Ekwenyeghi m nke ukwuu"), *Disagree* ("Ekwenyeghi m"), *Agree* ("Ekwere m"), and *Strongly Agree* ("Ekwere m nke ukwuu"). The bilingual format followed established practices in Nigerian educational research with pre-primary learners (Udegbe, 2024) and helped ensure that differences in English proficiency did not interfere with the accurate assessment of mathematical understanding or interest.

Responses were recorded on a four-point Likert scale: Strongly Disagree (1), Disagree (2), Agree (3), and Strongly Agree (4). Total scores ranged from 15 to 60, with higher scores indicating stronger interest. The four-point format (rather than five-point) was chosen to eliminate neutral response options, encouraging pupils to express a definite position while remaining simple enough for young children to comprehend. Table 3 presents the complete item set.

Table 3: Items from the Number and Numeration Interest Scale (NNIS)

Item No.	Statement
1	I participated actively in learning this addition.
2	I enjoyed solving by adding.
3	I would like to do it as an assignment at home.
4	I would like to invite my friends to join us in our next class.
5	I will teach my friends when I get home.
6	I will tell my siblings about this mathematics addition when I get home.
7	I enjoyed the class.
8	I like what you are teaching us.
9	I want us to be learning addition very often.

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Item No.	Statement
10	I want us to continue with the class.
11	I want us to have another class tomorrow.
12	I like to do Mathematics at higher level.
13	I would like to study addition at home.
14	I would like to be in the class when addition is taught.
15	I would like to continue learning addition.

Note. Cronbach's α = .95, indicating excellent internal consistency.

Validity and Reliability of Instruments

Content Validity. Both instruments underwent rigorous content validation. Initial item pools (20 items for NNAT, 30 items for NNIS) were developed based on the Nigerian ECCD III curriculum guidelines and reviewed literature on early numeracy assessment. Three experts in mathematics education, two specialists in educational psychology, and one measurement and evaluation scholar independently reviewed the instruments for content relevance, age-appropriateness, and clarity.

Experts rated each item on a 4-point scale (1 = not relevant, 4 = highly relevant) and provided qualitative feedback. Items with Content Validity Index (CVI) values below .80 were revised or eliminated. The final NNAT consisted of fifteen items with mean CVI = .92 (range: .83–1.00), and the final NNIS contained 15 items with mean CVI = .89 (range: .83–1.00). Experts also confirmed that language complexity was appropriate for 4–5-year-old Nigerian children familiar with English and Igbo instruction.

Face Validity. Prior to main data collection, both instruments were piloted with 12 ECCD III pupils from a different school not included in the study sample. Pupils were asked whether they understood each question, and researchers observed response patterns for signs of confusion. Minor wording adjustments were made based on this feedback (e.g., simplifying "participate actively" to "join in"). The pilot also

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confirmed that 30 minutes was sufficient for administration.

Reliability. Internal consistency reliability was estimated using Cronbach's alpha coefficient. For the NNAT, α = .91 (95% CI [.85, .95]), indicating that the fifteen items measured a unitary construct despite the small number of items. For the NNIS, α = .95 (95% CI [.92, .97]), demonstrating excellent internal consistency. These values exceed conventional thresholds for research instruments and are particularly strong given the young age of respondents. Table 4 summarizes reliability estimates.

Table 4: Reliability of Study Instruments

Instrument	No. of Items	Cronbach's α	95% CI
NNAT	15	.91	[.85, .95]
NNIS	15	.95	[.92, .97]

Data Screening and Preparation

All data were entered into R statistical software (version 4.4.1; R Core Team, 2024) and subjected to comprehensive screening procedures prior to analysis.

Missing Data. Initial examination revealed no missing data for demographic variables. Two cases (3.9% of sample) had incomplete post-test interest scale responses (one item each). These cases were retained after single imputation using the participant's mean score across completed items, as the proportion of missing data was minimal, and imputation preserved sample size.

Data Entry Accuracy. To verify accuracy, 20% of cases (n = 10) were randomly selected for double-entry verification. Discrepancies were identified in three data points (0.6% error rate), which were corrected by consulting original score sheets. This low error rate indicated acceptable data entry quality.

Univariate Outliers. Boxplots were generated for all continuous variables (pre-test achievement, post-test achievement, pre-test interest, post-test interest). Values exceeding

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1.5 times the interquartile range were flagged. Four potential outliers were identified: two high scores on post-test achievement (experimental group) and two low scores on post-test interest (control group). Visual inspection and review of raw responses confirmed these were legitimate values rather than errors, so all cases were retained.

Multivariate Outliers. Mahalanobis distance (D^2) was computed for each case to detect multivariate outliers. Using a critical value of χ^2 (4) = 18.47 at p = .001, no cases exceeded this threshold (maximum D^2 = 14.83). Therefore, no multivariate outliers were present.

Normality. Univariate normality was assessed via Shapiro-Wilk tests and visual inspection of Q-Q plots. All variables showed acceptable normality (all W > .96, all p > .30), with Q-Q plots displaying approximately linear patterns. Skewness values ranged from -0.42 to 0.38, and kurtosis values ranged from -0.63 to 0.51, all within acceptable limits (|skewness| < 1.0, |kurtosis| < 2.0).

Linearity. Scatterplots of covariates (pre-test scores) against dependent variables (post-test scores) revealed positive linear relationships with no evidence of curvilinearity. Pearson correlations were pre-test achievement with post-test achievement (r = .68, p < .001), pre-test interest with post-test interest (r = .64, p < .001).

These screening procedures confirmed that the dataset met quality standards and statistical assumptions necessary for MANCOVA.

Experimental Procedure

The intervention was implemented over five consecutive school days (one week), with one 30-minute lesson delivered each morning between 9:00-9:30 AM. This timing was selected to maximize pupils' alertness and minimize interference with other activities. Both groups completed pre-tests (NNAT and NNIS) on Monday morning before instruction commenced.

Experimental Group. Pupils in the experimental group (n=26) received play-based instruction using a card game designed to teach addition. Each lesson followed a structured progression: (1) Introduction (5 minutes): The researcher reviewed previous learning and introduced the day's objective; (2) Demonstration (5 minutes): The game rules were modeled using a sample round; (3) Group Play (15 minutes): Pupils were divided into groups of 4-5 and played the card game. The deck contained 20 cards showing "2," 16 cards showing "3," 18 cards showing "1," and 2

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"whot" (wild) cards. Cards were shuffled and distributed equally. Players took turns placing cards face-up while announcing cumulative sums aloud. The player whose card brought the sum to exactly 10 collected all cards from that round. Play continued until all cards were used. The winner was the player who collected the most cards; (4) Evaluation (5 minutes): Individual pupils solved written addition problems to demonstrate mastery.

The researcher circulated among groups during play, asking prompting questions ("What number do you need to make 10?"), correcting miscalculations, and encouraging strategic thinking. Emphasis was placed on verbalizing addition processes and recognizing number patterns. Lessons progressed from simple additions (1+1, 2+1) to more complex combinations (2+3+5, 1+4+5).

Control Group. Pupils in the control group (n=25) received conventional instruction at 10:00-10:30 AM to prevent cross-contamination. Lessons followed traditional Nigerian ECCD pedagogy: (1) Introduction (5 minutes): The researcher explained the concept of addition using everyday examples (e.g., combining fruits); (2) Demonstration (10 minutes): Addition problems were presented on the blackboard with step-by-step solutions. The researcher used counting objects (stones, sticks, straws) to demonstrate. For example, to solve 2+3, the researcher showed 2 stones, then 3 stones, combined them, and counted the total; (3) Guided Practice (10 minutes): Pupils used their own counting objects to solve problems dictated by the researcher, responding aloud in unison; (4) Individual Practice (5 minutes): Written addition problems were assigned for independent work.

The control group's approach emphasized procedural accuracy and memorization of basic facts through repetition. Pupils were passive recipients of teacher-directed instruction, with limited opportunity for exploration or peer interaction.

Fidelity and Contamination Control. To maintain consistency in instructional delivery, the researcher adhered strictly to standardized lesson plans and kept detailed field notes throughout the intervention to record and address any procedural variations. Both groups were taught identical mathematical content addition involving sums not exceeding ten and received the same instructional duration of 30 minutes daily over a five-day period. Several strategies were employed to minimize contamination between the experimental and control conditions. Conducting the

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DOI: https://doi.org/10.59231/SARI7897

intervention in two different schools prevented direct contact between pupils from the two groups, as the schools served distinct neighborhoods and catchment areas. Consequently, opportunities for after-school interaction or exchange of instructional information were highly unlikely. Furthermore, neither teachers nor school administrators were informed of their school's assigned condition, thereby reducing expectancy bias. Within each participating school, only one ECCD III class was involved in the study to prevent within-school diffusion of instructional strategies. Parents were also not briefed on the nature of the experimental and control conditions, which minimized the likelihood of home discussions influencing pupils' engagement. Collectively, these safeguards ensured high procedural fidelity and greatly reduced the potential for cross-group contamination, enhancing the internal validity of the study.

Post-Testing. On Friday afternoon, both groups completed post-tests (NNAT and NNIS) under standardized conditions. The researcher administered assessments orally to accommodate pupils' limited reading ability, recording responses on score sheets. Testing occurred in the regular classroom with pupils seated individually to prevent collaboration.

Results

The results are presented in alignment with the research questions and hypotheses. All analyses were conducted using R statistical software (version 4.4.1; R Core Team, 2024).

Preliminary Analysis: Baseline Equivalence

Prior to examining treatment effects, baseline equivalence between groups was assessed using independent samples t-tests on pre-test measures. Table 2 presents pre-test means, standard deviations, and group comparisons.

Table 5: Pre-Test Means, Standard Deviations, and Group Comparisons

Measure	Experimental (n=26)	Control (n=25)	t	df	p	Cohen's d
Achievement	38.46 (9.23)	39.20 (8.87)	0.30	49	.767	0.08

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ISSN: 2959-1376 DOI: https://doi.org/10.59231/SARI7897

Measure	Experimental (n=26)	Control (n=25)	t	df	p	Cohen's d
Interest	35.62 (8.14)	36.48 (7.92)	0.39	49	.696	0.11

Note. No significant differences were found between groups at baseline, indicating initial equivalence. Values in parentheses are standard deviations.

Independent samples t-tests revealed no significant differences between the experimental and control groups on pre-test achievement, t (49) = 0.30, p = .767, d = 0.08, or pre-test interest, t (49) = 0.39, p = .696, d = 0.11. The negligible effect sizes (d < 0.20) confirm that intact classes were well-matched at baseline, satisfying a key assumption for quasi-experimental designs.

Descriptive Statistics

Table 6 presents pre-test, post-test, and gain score means and standard deviations for mathematics achievement and interest by instructional group.

Table 6: Pre-Test, Post-Test, and Gain Score Means and Standard Deviations by Group

Measure	Group	Pre-Test M (SD)	Post-Test M (SD)	Gain Score M (SD)
Achievement	Experimental (n=26)	38.46 (9.23)	65.62 (6.91)	27.16 (8.45)
	Control (n=25)	39.20 (8.87)	39.68 (8.85)	0.48 (6.12)
Interest	Experimental (n=26)	35.62 (8.14)	60.38 (7.76)	24.76 (7.89)
	Control (n=25)	36.48 (7.92)	36.04 (7.29)	-0.44 (5.83)

Note. Gain scores represent post-test minus pre-test. M = mean; SD = standard deviation.

Descriptive statistics revealed substantial differences between groups on post-test measures. For achievement, the experimental group (M = 65.62, SD = 6.91) scored 25.94 points higher than the control group (M = 39.68, SD = 8.85), representing a raw

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difference of approximately 0.65 standard deviations. Similarly, for interest, the experimental group (M = 60.38, SD = 7.76) scored 24.34 points higher than the control group (M = 36.04, SD = 7.29).

Gain scores further illustrate the treatment contrast: the experimental group improved by 27.16 points on achievement and 24.76 points on interest, whereas the control group showed minimal change (0.48 points on achievement, -0.44 points on interest). These patterns suggest that the play-based intervention produced substantial improvements, while conventional instruction resulted in near-zero gains.

Assumption Testing for MANCOVA

All statistical assumptions for MANCOVA were systematically evaluated prior to hypothesis testing.

Univariate Normality. Shapiro-Wilk tests indicated acceptable normality for all dependent variables by group: experimental achievement (W = 0.96, p = .329), control achievement (W = 0.97, p = .643), experimental interest (W = 0.98, p = .872), and control interest (W = 0.97, p = .701). Visual inspection of Q-Q plots confirmed approximately linear patterns, supporting the normality assumption.

Linearity. Scatterplots of covariates (pre-test scores) against dependent variables (post-test scores) revealed positive linear relationships for both achievement (r = 0.68, p < .001) and interest (r = 0.64, p < .001), with no evidence of curvilinear patterns.

Homogeneity of Variance. Levene's test confirmed homogeneity of variance for post-test achievement, F (1, 49) = 1.89, p = .175, and post-test interest, F (1, 49) = 0.42, p = .519.

Homogeneity of Covariance Matrices. Box's M test yielded M = 6.83, F (6, 34820) = 1.08, p = .372, indicating that covariance matrices were homogeneous across groups.

Multicollinearity. Correlation between covariates was moderate (r = 0.58), and variance inflation factors (VIF = 1.51 and 1.48) were well below the threshold of 10, confirming absence of problematic multicollinearity.

Outliers. Mahalanobis distance analysis revealed no multivariate outliers exceeding the critical value of χ^2 (4) = 18.47 at p = .001. Two cases with standardized residuals exceeding ±2.5 were examined and retained as legitimate data points.

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All assumptions were adequately satisfied, supporting the appropriateness of MANCOVA for hypothesis testing.

Multivariate Analysis of Covariance (MANCOVA)

A one-way MANCOVA was conducted to test whether instructional method (play-based vs. conventional) influenced post-test achievement and interest after controlling for pre-test scores. Table 4 presents the multivariate and univariate results.

Table 7: MANCOVA Results: Effect of Instructional Method on Achievement and Interest

Test/Variable	**F**	**df**	**Error df**	**p**	**η²**	**Observed Power**
Multivariate (Wilks' Λ = .23)	78.35	2	46	< .001	.77	> .99
Univariate Tests						
Achievement	136.72	1	47	< .001	.74	> .99
Interest	142.55	1	47	< .001	.75	> .99

Note. Covariates were pre-test achievement and pre-test interest. Effect sizes (η^2) represent the proportion of variance in post-test scores attributable to instructional method after controlling for pre-test scores.

The multivariate test indicated a statistically significant effect of instructional method on the combined dependent variables, Wilks' $\Lambda = .23$, $F(2, 46) = 78.35$, $p < .001$, $\eta^2 = .77$. This large multivariate effect size ($\eta^2 = .77$) suggests that instructional method accounted for approximately 77% of the variance in the combined outcome measures after adjusting for baseline differences.

Univariate Follow-Up Tests. Given the significant multivariate effect, univariate ANCOVAs were examined for each dependent variable. Results revealed significant effects of instructional method on both achievement, $F(1, 47) = 136.72$, $p <$

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.001, $\eta^2 = .74$, and interest, $F(1, 47) = 142.55$, $p < .001$, $\eta^2 = .75$. These effect sizes are exceptionally large by conventional standards (Cohen, 1988), indicating that instructional method explained approximately 74% of post-test achievement variance and 75% of post-test interest variance after controlling for pre-test scores.

Adjusted Means. Table 5 presents estimated marginal means (adjusted for pre-test scores) with 95% confidence intervals.

Table 8: Adjusted Post-Test Means and 95% Confidence Intervals by Group

Measure	Experimental (n=26)	Control (n=25)	Mean Difference	95% CI
Achievement	65.48 [62.91, 68.05]	39.82 [37.18, 42.46]	25.66	[21.84, 29.48]
Interest	60.26 [57.85, 62.67]	36.16 [33.67, 38.65]	24.10	[20.55, 27.65]

Note. Adjusted means control for pre-test scores. CI = confidence interval.

After adjusting for baseline differences, the experimental group scored 25.66 points higher on achievement (95% CI [21.84, 29.48]) and 24.10 points higher on interest (95% CI [20.55, 27.65]) than the control group. The confidence intervals do not contain zero, confirming statistically significant differences favoring the play-based approach.

Hypothesis Testing

The study tested two null hypotheses at $\alpha = .05$.

Hypothesis 1: There is no significant difference in achievement between pupils taught mathematics addition with play-based strategies and those taught with conventional methods.

Decision: The null hypothesis was rejected, $F(1, 47) = 136.72$, $p < .001$, $\eta^2 = .74$. Pupils receiving play-based instruction demonstrated significantly higher achievement than those receiving conventional instruction.

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ISSN: 2959-1376
2026, Vol. 05, Issue 01, 174-203
DOI: https://doi.org/10.59231/SARI7897

Hypothesis 2: There is no significant difference in interest between pupils taught mathematics addition with play-based strategies and those taught with conventional methods.

Decision: The null hypothesis was rejected, $F (1, 47) = 142.55$, $p < .001$, $\eta^2 = .75$. Pupils receiving play-based instruction reported significantly greater interest in mathematics than those receiving conventional instruction.

Effect Size Interpretation

The observed effect sizes ($\eta^2 = .74$ for achievement, $\eta^2 = .75$ for interest) are exceptionally large. Cohen (1988) classified $\eta^2 \geq .14$ as large effects; the present study's effects exceed this benchmark by more than fivefold. To contextualize these magnitudes, several factors warrant consideration.

First, the focused instructional target single-digit addition without carrying represents a discrete, foundational skill that may be more amenable to rapid improvement than complex mathematical concepts. Second, the developmental appropriateness of play-based methods for preoperational children (ages 4-5) may have optimized learning conditions, as the approach aligns with children's concrete thinking and natural inclination toward play (Piaget, 1952). Third, the contrast with baseline practice was substantial; the control group's rote, teacher-directed approach differs markedly from the experimental group's active, game-based engagement, potentially amplifying treatment effects. Fourth, novelty effects cannot be ruled out. The card game represented a departure from typical classroom activities, likely generating heightened motivation that may attenuate over time (Abrami et al., 2008).

While these factors contextualize the large effects, they underscore the need for cautious interpretation. The one-week intervention period may have captured peak engagement before habituation occurred, and the absence of delayed assessment prevents conclusions about retention. Nonetheless, the practical significance is clear: play-based instruction produced substantial short-term gains in both achievement and affect.

Summary of Findings

This study examined whether play-based instructional strategies enhance pre-primary pupils' mathematics achievement and interest compared with conventional methods. Results support two primary conclusions:

1. Achievement Effects. Play-based instruction significantly improved

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ISSN: 2959-1376
DOI: https://doi.org/10.59231/SARI7897

mathematics achievement. After controlling for baseline differences, pupils in the experimental group scored 25.66 points higher (on a 100-point scale) than control group peers, representing a difference of approximately 2.9 standard deviations. This large effect ($\eta^2 = .74$) demonstrates that play-based strategies substantially enhanced computational accuracy on basic addition tasks.

2. Interest Effects. Play-based instruction significantly increased mathematics interest. Experimental group pupils reported interest scores 24.10 points higher (on a 60-point scale) than control group pupils, reflecting heightened enjoyment, engagement, and desire for continued mathematics learning. This large effect ($\eta^2 = .75$) suggests that play-based pedagogy fosters positive affective responses to mathematics.

Together, these findings indicate that incorporating game-based activities into early mathematics instruction can simultaneously enhance cognitive outcomes (achievement) and affective outcomes (interest), addressing both performance and motivational dimensions of mathematical learning.

Discussion

The purpose of this study was to investigate whether play-based instructional strategies could improve mathematics outcomes for pre-primary pupils compared to conventional teaching approaches. The results showed that pupils exposed to play-based lessons outperformed their peers in both achievement and interest. These findings highlight the importance of aligning early mathematics instruction with children's developmental readiness and preferred modes of learning.

Interpretation of Results

The strong improvements observed among pupils in the experimental group are consistent with developmental theories. Piaget (1952, 1964) argued that young children construct knowledge through active interaction with their environment rather than passive reception. In this study, card games provided opportunities for manipulation, discovery, and social interaction, processes that Piaget identified as essential for meaningful learning. Similarly, Dienes (1960, 1971) described six stages of mathematical learning in which children move from playful exploration to abstract reasoning. The intervention's design mirrored this developmental sequence, likely explaining why pupils were able to grasp

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ISSN: 2959-1376
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addition concepts quickly and retain interest throughout the sessions.

The motivational benefits observed also align with research linking play to positive attitudes toward mathematics. Siegler and Ramani (2009) found that structured board games improved low-income children's number sense, while Reikerås (2020) reported that play skills predicted later mathematics competence in toddlers. These studies, like the current findings, confirm that active and playful engagement makes mathematics both enjoyable and cognitively effective.

Relation to Previous Studies

The present findings are consistent with work in African contexts showing that playful strategies enhance numeracy. Taiwo (2023) and Udegbe (2024) both reported that game-based approaches improved pupils' mathematics performance in Nigerian classrooms. At a broader level, reviews by Palmér and van Bommel (2018) and Louw and Claassens (2025) have demonstrated across multiple settings that embedding mathematical concepts into play activities enhances both achievement and motivation. Together, this body of research confirms that play-based pedagogy is effective across cultures and is particularly relevant in Nigeria, where conventional rote approaches remain dominant.

Interpreting the Magnitude of Effects

The observed effect sizes in this study were unusually large ($\eta^2 = .74$ for achievement; $\eta^2 = .75$ for interest). By comparison, Cohen (1988) classified $\eta^2 \geq .14$ as a large effect. Several factors may account for the magnitude of these results.

First, the intervention targeted a narrow and foundational objective addition of single-digit numbers not exceeding ten. Research shows that when instruction is specific and developmentally appropriate, gains can be achieved rapidly (Siegler & Ramani, 2009). Second, pupils in ECCD III (ages 4–5) are at a critical stage for number sense development, making them highly responsive to hands-on, engaging instruction. Third, the control group's instruction relied heavily on rote counting, which created a sharp contrast with the experimental group's playful methods, thus widening the treatment effect. Fourth, the novelty of using card games may have heightened motivation and attention, a phenomenon often observed in short-term interventions (Abrami et al., 2008). Finally, the five-item test, scored on a 100-point

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ISSN: 2959-1376
2026, Vol. 05, Issue 01, 174-203
DOI: https://doi.org/10.59231/SARI7897

scale, may have amplified differences, since each correct response carried substantial weight.

Although these factors help contextualize the findings, they do not diminish the practical significance. Even if some effects attenuate over time, the immediate improvements demonstrate that play-based strategies engage learners effectively and promote rapid gains in mathematics. The key challenge for future research is to examine whether these gains consolidate into lasting conceptual understanding and transfer to more advanced mathematics topics.

Limitations

Several limitations warrant consideration when interpreting these findings.

Intervention Duration. The one-week intervention period, while producing statistically significant effects, raises questions about sustainability. The large effect sizes (η^2=.74-.75) may partly reflect heightened engagement with novel activities rather than deep conceptual mastery. Without delayed post-testing, we cannot determine whether observed gains represent temporary performance increases or durable learning. Future research should extend intervention duration to 6-8 weeks and include follow-up assessments at 2-week and 4-week intervals to examine retention and decay patterns.

Sample Characteristics. The study sample consisted of 51 pupils drawn from intact Early Child Care Development (ECCD) III classes in two urban public primary schools in Enugu East. While this approach provided practical access to comparable learning environments, it also introduced several limitations affecting generalizability.

First, although both schools were selected based on institutional equivalence, factors not directly measured such as administrative leadership, school climate, or community support could have contributed to observed outcomes. Second, using intact classes rather than randomly assigning individual pupils raises the possibility of selection bias; however, comparable pre-test scores and similar demographic profiles between groups helped to reduce this threat. Third, since both schools were urban and publicly managed, the findings may not extend to private or rural schools, or to other regions of Nigeria where language, socioeconomic conditions, and infrastructure differ. Finally, purposive school selection, driven by logistical feasibility and administrative consent, may limit representativeness. Future research

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ISSN: 2959-1376
2026, Vol. 05, Issue 01, 174-203
DOI: https://doi.org/10.59231/SARI7897

employing stratified random sampling across multiple school types and geographic locations would enhance the external validity of these findings.

Contextual Constraints. The study was conducted in an urban public school with relatively favorable conditions (functional classrooms, available materials, supportive administration). Results may not generalize to resource-poor rural schools, overcrowded classrooms, or contexts with insufficient instructional materials. Implementation research examining feasibility, acceptability, and effectiveness across diverse Nigerian educational settings is needed.

Despite these limitations, this study provides rigorous evidence for play-based strategies' potential in Nigerian pre-primary mathematics education. The use of validated instruments, pre-post assessment with covariates, attention to assumption testing, and transparent reporting of effect sizes strengthen confidence in findings within acknowledged boundaries.

Conclusion

This study provides empirical evidence that play-based strategies significantly enhance pre-primary pupils' mathematics achievement and interest in Nigerian contexts. The use of card games to teach addition produced large effects on both cognitive (achievement) and affective (interest) outcomes, supporting theoretical predictions from Piagetian constructivism and Dienes' stage theory. Findings suggest that integrating play-based approaches into Nigerian ECCD curricula could address persistent challenges in early mathematics learning.

However, the brief intervention duration and single-site sample necessitate cautious interpretation. The exceptional effect sizes likely reflect a combination of effective pedagogy, developmental appropriateness, and novelty effects. Determining which components contribute most to effectiveness and whether effects sustain over time requires systematic replication and extension.

Directions for Future Research

Building on these preliminary findings, we recommend four research priorities:

1. Longitudinal Extension. Replicate with 8–12-week interventions and delayed post-tests at 1 month and 3 months to assess retention, consolidation, and potential decay patterns.

2. Multi-Site Implementation. Conduct cluster-randomized trials across 6-10 schools representing diverse contexts (urban/rural,

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ISSN: 2959-1376
2026, Vol. 05, Issue 01, 174-203
DOI: https://doi.org/10.59231/SARI7897

public/private, high/low resource) to evaluate generalizability and implementation feasibility under varied conditions.

3. Component Analysis. Employ factorial designs to identify active ingredients (e.g., competition, verbalization, peer interaction, manipulative use) and optimal dosage parameters.

4. Scale-Up Research. Investigate teacher-delivered implementation with professional development support, examining fidelity, adaptation, sustainability, and cost-effectiveness for policy consideration.

Practical Implications

For practitioners and policymakers, findings suggest that:

- Simple, low-cost materials (card decks) can effectively teach foundational mathematics
- Play-based approaches engage pupils who might otherwise disengage from abstract instruction
- Teacher education programs should include training on designing and facilitating mathematical games
- Curriculum frameworks should explicitly incorporate play-based strategies for ECCD mathematics

While questions about long-term effectiveness remain, this study demonstrates that play-based pedagogy merits serious consideration as a strategy for improving early mathematics learning in Nigerian schools.

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Received on Oct 25, 2025
Accepted on Nov 28, 2025
Published on Jan 01, 2026