European Journal of Education Studies
ISSN: 2501 - 1111
ISSN-L: 2501 - 1111
Available online at: www.oapub.org/edu

DOI: 10.46827/ejes.v13i6.6670 Volume 13 | Issue 6 | 2026

EFFECT OF TEACHER-GUIDED DOUGH-BASED INSTRUCTIONAL METHOD ON PRESCHOOL CHILDREN'S PERFORMANCE IN ADDITION SKILLS IN EMBAKASI EAST SUB-COUNTY, KENYA

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Abstract:
The development of foundational addition skills during early childhood forms the basis for later mathematical learning. However, many preschool learners experience difficulties in grasping abstract numerical concepts when instruction relies primarily on traditional, teacher-centered approaches. This study investigated the effect of teacher-guided dough-based instructional method on preschool children's acquisition of addition skills in Embakasi East Sub County. Guided by Vygotsky's Social Constructivist Theory and a post-positivist paradigm, the study employed a quantitative quasi-experimental design involving two intact PP2 classes assigned to experimental and control groups. Data were collected using pre-test and post-test assessments and analyzed using descriptive and inferential statistics in SPSS. The findings revealed that learners exposed to teacher-guided dough-based instruction achieved significantly higher addition scores than those taught using conventional methods, t (36) = −2.168, p = .037, with a large effect size (Cohen's $d \approx 0.72$). The study concludes that teacher-guided dough-based play is an effective approach for enhancing preschool learners' addition skills and recommends its integration into early mathematics instruction to strengthen numeracy outcomes.

Keywords: dough-based instruction, guided play, preschool mathematics, addition skills, early childhood education

1. Introduction

Early childhood is a critical period for cognitive, social, and emotional development, during which children acquire foundational skills that shape later learning (Zhou *et al.*, 2024). Early mathematics is particularly important for long-term academic success, as experiences such as counting, number recognition, and basic operations strengthen logical reasoning, problem-solving, and school readiness (Dowker, 2023; Petropoulou *et*

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al., 2024). Many education systems have therefore adopted play-based and inquiry-oriented approaches that reflect how young children learn through exploration and manipulation. Teachers increasingly use concrete materials such as blocks, beads, and play dough to support understanding of number sense and addition (Chan & Scalise, 2022). Evidence shows that learning becomes more effective when play is intentionally guided by teachers through questioning, prompts, and modeling, which help connect children's experiences with mathematical ideas (Clements *et al.*, 2021).

Studies from Australia and Finland confirm that structured, teacher-guided play improves counting, number relationships, and early addition skills, demonstrating the value of intentional pedagogy in early mathematics (Papic *et al.*, 2021; Papadakis *et al.*, 2024). In many Sub-Saharan African contexts, however, implementation of play-based pedagogy remains limited. In Kenya, inadequate teacher preparation, large class sizes, and limited resources continue to constrain effective practice despite the Competency-Based Education framework that promotes child-centered learning (Ogego & Aina, 2025; Muema *et al.*, 2023). Teachers frequently rely on traditional, teacher-directed methods and receive little professional development on the use of affordable materials such as play-dough for structured numeracy instruction (Murungi, 2018).

This challenge is evident in Embakasi East Sub-County, where early numeracy is low. KNEC (2017) reported that only 52% of pre-primary learners were competent in mathematics, while Uwezo (2017) found 60% lacked basic skills and 34% could not perform simple numeracy tasks. These gaps underscore the need for developmentally appropriate strategies to improve addition skills and overall mathematical readiness.

1.1 Purpose of the Study

The purpose of this study was to examine the effect of teacher-guided dough-based instructional method on preschool children's performance in addition skills in Embakasi East Sub-County, Kenya.

1.2 Objective of the Study

To establish the effect of teacher-guided dough-based instructional method on preschool children's performance in addition skills in Embakasi East Sub-County.

2. Literature Review

Studies across diverse educational contexts indicate that manipulative-based instruction significantly enhances preschool children's mathematics performance, particularly in foundational skills such as addition. According to Hyun and Davis (2021), play-oriented mathematics environments increase children's motivation and time on task, which are critical predictors of early numeracy achievement. Similarly, Zosh *et al.* (2022) report that playful, sensory learning contexts promote persistence and strategic thinking, resulting in stronger performance on early number tasks compared to traditional worksheet-based approaches. In their empirical study on preschool mathematics instruction, Boz, Uludağ,

and Erdoğan (2020) found that children who learned using manipulatives scored significantly higher on the Test of Early Mathematics Ability than peers taught through conventional methods ($p < .05$). The authors concluded that concrete materials directly enhanced children's understanding of number operations, including addition and decomposition of quantities.

According to RTI International (2018), a play-based mathematics program in Ethiopia, Rwanda, and Mozambique led to children exposed to manipulative-rich instruction achieving a 49% improvement in mathematics assessment scores within five months, compared with only 13.9% and 1.9% gains in comparison groups. The greatest improvements occurred in number recognition and combining quantities, foundational skills for addition. A meta-analysis by de Chambrier *et al.* (2021) synthesized results from numerous early mathematics interventions and reported a moderate overall effect size ($d \approx 0.62$) for programs using manipulatives and guided play, emphasizing that performance gains were strongest when teachers guided children to physically represent addition problems before introducing symbols.

According to Mattoon *et al.* (2015), children who participated in hands-on numeracy activities significantly improved their computational scores from $M = 1.50$ to $M = 2.83$ ($p = .010$), while peers in non-manipulative classrooms showed minimal change. The authors attributed these gains to children modeling addition problems with physical objects, which enhanced conceptual understanding and problem-solving. In their longitudinal study, Ramani *et al.* (2019) found that children regularly engaging with number toys and manipulatives demonstrated higher mathematics achievement one year later, even after controlling for prior ability, with particularly strong performance in addition and number comparison tasks.

According to Mitei and Mwoma (2021), teachers reported that locally available resources such as clay and improvised dough improved children's accuracy in matching, counting, and combining quantities, with noticeable improvement in addition tasks and greater learner independence after several weeks of manipulative-based activities. Collectively, these studies demonstrate that teacher-guided manipulative instruction consistently produces measurable improvements in early mathematics performance, particularly in skills underlying addition. Despite this evidence, most research has been conducted in typical or metropolitan preschools, which may not fully reflect the unique conditions of Embakasi East Sub-County. This study seeks to address this gap by evaluating how manipulative-based activities impact the development of addition skills within this specific context.

3. Material and Methods

3.1 Research Design

Guided by the post-positivist paradigm, the study employed a quasi-experimental design to examine the effect of teacher-guided dough-based instruction on preschool children's addition skills. The post-positivist paradigm emphasizes systematic inquiry, empirical

testing, and measurable outcomes to approximate objective knowledge (Kaushik & Walsh, 2021; Maksimović & Evtimov, 2023). Data were collected from preschool children in both experimental and control groups. This design enabled the investigation of cause-and-effect relationships in natural classroom settings, providing practical, evidence-based insights into the impact of manipulative-assisted instruction (Alase, 2021; Privitera, 2023).

3.2 Study Area and Population

The study was conducted in Embakasi East Sub-County, Nairobi County, covering 11.5 km² within Nairobi's 696 km² area. The sub-county was selected for the study because of its dense population, rapid growth, and high demand for early childhood education services (KNBS, 2019). Embakasi East sub-county hosts numerous small to medium-sized private preschools, typically located in residential neighbourhoods, serving playgroup, Pre-Primary One (PP1), and Pre-Primary Two (PP2) learners under the Competency-Based Education (CBE) system. The private preschools in Embakasi East sub-county were chosen for the study because they enrol a significant proportion of preschool learners and are equally mandated by the Ministry of Education to implement CBE.

3.3 Sampling Techniques and Sample Size

A stratified random sampling technique was employed to ensure a representative selection of private preschools. Embakasi East Sub-County was first stratified into its five wards, after which Embakasi Ward was randomly selected. Subsequently, preschool teachers were randomly chosen from private preschool centers within the selected ward. The sample size for the study was determined using Cochran's (1977) formula for an unknown population. The formula is appropriate for large or indeterminate populations because it provides a statistically sound method of estimating a representative sample based on a chosen confidence level and margin of error (Uakarn *et al.,* 2021). A 95% confidence level (Z = 1.96) was used, as it is standard in social and educational research, providing a high level of certainty while maintaining a reasonable sample size (Taherdoost, 2016). The margin of error was set at e=0.1 (10%) because it balances feasibility and acceptable precision for an educational study of this scale, allowing reliable results while keeping the sample size manageable (Huyler & McGill, 2019). Since the population proportion of private preschool teachers in Embakasi East Sub-County was unknown, p=0.5 was therefore used to maximize the required sample size.
The formula is expressed as:

$$n = \frac{Z^2 * p(1-p)}{e^2}$$

Substituting these values into the formula:

$$n = \frac{1.96^2 * 0.5 * 0.5}{0.1^2}$$

$$n = \frac{3.8416 * 0.25}{0.01}$$

$$n = \frac{0.9604}{0.01}$$

$$n = 96.04$$

The minimum sample size required for the study was 96.

3.4 Data Collection Instruments and Procedure

Data were collected using a standardized assessment test administered to preschool children during both the pretest and posttest phases of the study. The assessment consisted of simple addition tasks designed to measure children's competency in basic addition concepts appropriate for their developmental level. Prior to the main study, the assessment tool was pretested with preschool children in two centers outside the study area, and minor adjustments were made to improve clarity and suitability for the learners. The assessments were administered to the children by the researcher after obtaining permission from the school administrators and informed consent from the parents or guardians. The pretest was conducted before the intervention, and the posttest was administered after the intervention period to measure changes in the children's addition skills.

3.5 Data Analysis

To evaluate the effectiveness of the intervention, data were analyzed using descriptive statistics to summarize learners' performance and independent samples t-tests to determine whether significant differences existed between the experimental and control groups' post-test scores. To further establish the practical significance of this finding, Cohen's *d* was calculated using the t-value from the independent samples test to indicate the practical significance of the intervention, with effect sizes interpreted as small (around 0.2), medium (around 0.5), or large (around 0.8).

3.6 Ethical Considerations

The researcher obtained an introductory letter from Moi University to present to relevant authorities, followed by a research permit from NACOSTI, clearance from the Nairobi County Commissioner, the Regional Director of Education, and final approval from the Embakasi East Sub-County Director of Education. These approvals authorized access to private preschools and participants in the sub-county. Informed consent was obtained from preschool teachers and from parents/guardians of children in the experimental and control groups. Children were informed of the activities in an age-appropriate manner and could withdraw without consequence; however, all completed the intervention. Confidentiality was maintained by anonymizing personal identifiers, and data were

securely stored in compliance with the Kenya Data Protection Act (2019) and international privacy standards (WHO, 2011). The study minimized risks by conducting dough play activities within familiar classroom schedules under teacher supervision, ensuring no physical or psychological harm. The researcher conducted the study with honesty, fairness, and transparency, with no conflicts of interest, as participants were not previously known to the researcher.

4. Results and Discussion

The effect of teacher-guided dough-based instruction on preschool children's addition skills was examined by comparing the pre-test and post-test scores of the experimental and control groups. An independent samples t-test was conducted to determine whether the intervention led to significant differences in addition skill performance. The pre-test scores were analyzed to ensure that the two groups were comparable. As shown in Table 1.

Table 1: Descriptive statistics for pre-test and post-test addition scores

	Group	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Pre-test Group	Control Group	17	82.94	13.585	3.295
	Experimental Group	21	80.48	12.032	2.626
Post-test Group	Control Group	17	86.1765	13.29114	3.22358
	Experimental Group	21	93.5714	7.44024	1.62359

The descriptive statistics of post-test mathematics scores presented in Table 1 show that, before the intervention, pretest scores indicated that the control group (M = 82.94, SD = 13.585) and the experimental group (M = 80.48, SD = 12.032) were roughly equivalent in performance. After the intervention, post-test scores showed that children in the experimental group (M = 93.57, SD = 7.44) outperformed those in the control group (M = 86.18, SD = 13.29). Additionally, an independent samples t-test was carried out to determine whether there was a statistically significant difference in post-test addition scores between the experimental and control groups, as shown in Table 2.

Levene's Test for Equality of Variances for the pre-test scores as shown on Table 2 above indicated that the assumption of equal variances was met ($F = 0.149$, $p = 0.702 > 0.05$). The independent samples *t*-test showed no statistically significant difference between the experimental and control groups at pretest ($t = 0.593$, $df = 36$, $p = 0.557 > 0.05$), with a mean difference of 2.465 (95% CI: −5.968 to 10.898). This confirms that both groups were comparable at baseline, thereby providing a valid foundation for evaluating the effect of the intervention.

Table 2: Independent sample t-test for pre-test and post-test addition scores

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Pre-test Group	Equal variances assumed	.149	.702	.593	36	.557	2.465	4.158	-5.968	10.898
	Equal variances not assumed			.585	32.339	.563	2.465	4.213	-6.113	11.043
Post-test Group	Equal variances assumed	3.081	.088	-2.168	36	.037	-7.394	3.410	-14.313	-.47839
	Equal variances not assumed			-2.049	23.916	.052	-7.394	3.609	-14.846	.05578

For the post-test scores, Levene's Test indicated that the assumption of equal variances was not violated ($F = 3.081$, $p = 0.088 > 0.05$). The independent samples *t*-test further revealed a statistically significant difference between the experimental and control groups ($t = -2.168$, $df = 36$, $p = 0.037 < 0.05$), with a mean difference of −7.395 (95% CI: −14.312 to −0.478). Based on the comparison of the post-test *p*-value ($p = 0.037$) with the 0.05 significance level ($\alpha = 0.05$), the null hypothesis ($\mathbf{H_{01}}$) was rejected, indicating that teacher-guided dough-based instructional method had a statistically significant effect on preschool children's addition skills. To further establish the practical significance of this result, Cohen's d was calculated from the independent samples t-test, yielding a value of approximately **0.72**.

This suggests that the statistically significant difference observed between the post-test mean addition scores of the experimental group and those of the control group was also educationally meaningful, with learners in the experimental group outperforming those taught using conventional instructional methods. These findings corroborate earlier studies showing that play-based strategies help children grasp abstract mathematical concepts by turning them into tangible experiences that boost motivation and engagement (Hyun & Davis, 2021; Zosh *et al.*, 2022). They also support Akinboboye *et al.* (2022) argument that using dough to model numbers and equations promotes deeper conceptual understanding of addition compared to rote memorization.

5. Conclusion

The study established that the teacher-guided dough-based instructional method has a statistically significant positive effect on preschool children's performance in addition.

Children exposed to this method consistently outperformed those taught using conventional instructional approaches, demonstrating its effectiveness. Moreover, the use of dough-based instruction enhances meaningful learning, supporting the development of addition skills in an engaging and hands-on manner.

6. Recommendations

The study recommends expanding the use of teacher-guided dough-based instruction to improve children's addition skills, as this approach has demonstrated a positive impact on preschool learners' mathematical performance. Schools and education authorities should therefore prioritize its integration into early childhood programs and support structured training for preschool teachers. Such training should equip teachers with practical skills to implement dough-based activities effectively and to utilize locally available materials in creating meaningful, hands-on learning experiences. By strengthening teachers' capacity in this approach, children's active participation will be enhanced, leading to improved numeracy skills and a deeper understanding of mathematical concepts.

Conflict of Interest Statement
The author declares no conflicts of interest.

About the Author(s)
Joseph Onyango is an early childhood education professional and researcher with a Bachelor of Education in Early Childhood Education from the University of Nairobi and a Master of Education in Research from Moi University. A DAAD scholar, his research interests focus on Latent Variable Modeling, Longitudinal and Cross-Sectional Data Analysis, Development of competencies of early childhood educators and Mathematical Education of children in the range of age from 0 to 6 years.

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