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Improving Numeracy Skills in Children Aged 4-5 Years Through Dough Play Activities: A Classroom Action Research

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ABSTRACT

Purpose of the study: Numeracy is a foundational cognitive skill for young children that underpins subsequent academic achievement. However, conventional rote-based instruction methods have proven ineffective in fostering genuine number sense in early childhood settings. Purpose: This study aimed to investigate whether dough play activities could improve the numeracy skills of 4–5-year-old children at TK Al-Muhadjirin 2, East Bekasi, Indonesia.

Materials and methods: A Classroom Action Research (CAR) design was employed across two cycles (10 sessions total), involving 12 children aged 4–5 years. Numeracy performance was assessed using structured observation instruments covering number concept, number symbol recognition, number sequencing, number matching, number-to-object correspondence, and numeral writing. Data were analyzed using percentage calculations and qualitative thematic analysis.

Results: Mean numeracy scores improved from 54% (pre-intervention) to 74% at end of Cycle I, and to 82% at end of Cycle II, exceeding the predetermined success threshold of 71%. All 12 participants demonstrated measurable improvement across all assessed numeracy indicators.

Conclusions: Dough play activities constitute a developmentally appropriate, multisensory pedagogical intervention that significantly enhances numeracy competence in early childhood. The tactile-kinesthetic engagement afforded by dough manipulation supports concrete understanding of number concepts, facilitating the transition from enactive to symbolic mathematical reasoning.

Keywords

numeracy skills; dough play; early childhood education; play-based learning; classroom action research; number concept; manipulative learning.

INTRODUCTION

Mathematics constitutes a fundamental discipline applicable across all domains of human activity, including commercial transactions, measurement, temporal reasoning, and scientific inquiry (Jannah, 2011). Within the developmental context of early childhood, mathematical learning facilitates cognitive growth by supporting problem-solving, classification, measurement, and the development of number concepts. Numeracy—the capacity to understand, use, and apply numbers—represents a critical precursor to formal academic readiness (Aunio & Räsänen, 2016; Jordan et al., 2009).

Early childhood education (ECE) settings provide a critical window for establishing number sense, defined as the intuitive understanding of numbers and their relationships (Berch, 2005). Research consistently demonstrates that early numeracy competencies are robust predictors of later mathematical achievement and broader academic outcomes (Duncan et al., 2007; Nguyen et al., 2016). Accordingly, the quality and appropriateness of numeracy instruction in kindergarten and preschool settings carries substantial long-term educational significance.

Critical Examination of Existing Literature

Contemporary research in early childhood mathematics education strongly advocates for play-based, hands-on pedagogical approaches over traditional didactic methods (Björklund et al., 2021; Clements & Sarama, 2014). Conventional instruction relying solely on whiteboard demonstrations and worksheet completion has been critiqued for failing to engage young learners meaningfully, producing superficial number memorization rather than genuine conceptual understanding (Baroody et al., 2006).

Manipulative-based learning—where children interact with physical objects to construct mathematical understanding—aligns with Bruner's (1966) three modes of representation: enactive (concrete manipulation), iconic (visual representation), and symbolic (abstract notation). Bruner's framework posits that durable mathematical understanding is built progressively from the enactive through the symbolic mode, necessitating concrete object-based experiences in early learning.

Play dough (hereafter 'dough') has been identified as a versatile and engaging medium for early childhood learning. Swartz (2005) observed that children spontaneously engage in counting, measuring, and shape comparison while playing with dough, making it a naturalistic medium for mathematical exploration. Similarly, Lee and Richards (2013) documented that dough play supports mathematical skill development by enabling children to construct three-dimensional representations of letters and numerals, facilitating concrete understanding of symbolic systems.

Previous action research by Wildayenti (2012) demonstrated significant numeracy improvements in kindergarten children through number card games, with 87.5% of participants successfully identifying numerals 1–10. Research involving food-based

manipulatives (traditional Indonesian foods) at an elementary school in Sleman, Yogyakarta, similarly reported improved mathematical understanding through concrete, edible objects (Kompas, 2015). These findings collectively support the efficacy of concrete, playful learning media for numeracy development.

Identification of Research Gaps

Despite the established theoretical and empirical support for manipulative-based mathematics instruction, the specific application of dough as a structured numeracy learning medium in Indonesian ECE contexts remains underexplored. Most existing studies have focused on discrete numeracy sub-skills (e.g., numeral recognition) rather than comprehensively addressing the full spectrum of early numeracy competencies. Additionally, the integration of sensory-motor engagement through dough manipulation with explicit numeracy instruction has not been systematically examined in Indonesian kindergarten populations.

Rationale and Objectives

This study addresses these gaps by investigating the effect of structured dough play activities on the numeracy skills of children aged 4–5 years at TK Al-Muhadjirin 2, Aren Jaya, East Bekasi, Indonesia. Pre-intervention observations revealed that the majority of children demonstrated inadequate numeracy competence, attributed to reliance on conventional, non-varied instructional approaches. The study sought to develop and implement a systematic dough-based numeracy intervention and evaluate its effectiveness. The specific objectives of this study were: (1) to describe the implementation of structured dough play activities as a numeracy learning intervention; (2) to assess changes in children's numeracy performance across pre-intervention, Cycle I, and Cycle II phases; and (3) to evaluate the effectiveness of dough play in improving the following numeracy indicators: number verbalization, number matching, number sequencing, object counting, number-symbol recognition, number-symbol sequencing, number-symbol matching, and numeral writing.

MATERIALS AND METHODS

Participants

The study involved 12 children ($n = 12$) enrolled in Group A (ages 4–5 years) at TK Al-Muhadjirin 2, Aren Jaya, East Bekasi, East Java, Indonesia. The original class comprised 15 children; 3 children were excluded due to incomplete attendance across intervention cycles. The remaining 12 participants (coded AA–AL) constituted the final analytical sample. Children's age range was 4 years 0 months to 5 years 11 months, consistent with Indonesian Ministry of Education and Culture classifications for early childhood Group A. Two qualified early childhood educators served as teaching staff in the classroom.

Study Organization and Design

A Classroom Action Research (CAR; Penelitian Tindakan Kelas) design was employed, following the cyclical model proposed by Kemmis and McTaggart (1988), comprising four iterative phases: Planning (Perencanaan), Action (Tindakan), Observation (Pengamatan), and Reflection (Refleksi). The study was conducted across two cycles, each comprising five intervention sessions (10 sessions total). Data collection occurred between November 2, 2015 and November 21, 2015.

The pre-intervention assessment was conducted on November 2, 2015. Cycle I spanned November 3–9, 2015 (five sessions), and Cycle II spanned November 16–21, 2015 (five sessions). The predetermined success criterion was a class mean of $\geq 71\%$, established through researcher-collaborator consensus prior to implementation.

The dough material used was prepared according to Indonesian Ministry of Education and Culture (Direktorat PAUD, 2014) guidelines, comprising food-safe ingredients: flour, oil, food coloring, water, and salt. Dough was prepared in four colors (red, orange, green, blue) to support color recognition and maintain child engagement.

Intervention Procedures

Each session followed a structured sequence: (a) morning assembly and opening activities (7:30–8:30), (b) thematic introduction and numeracy warm-up (8:30–8:50), (c) dough play activity (8:50–9:30), and (d) review and reflection (9:30–9:45). The researcher served as the primary teacher-researcher (guru peneliti), while the classroom teacher functioned as a collaborating observer (kolaborator).

Cycle I numeracy activities incorporated the following dough tasks: Session 1—constructing fish and fish eyes (numbers 1–10); Session 2—constructing turtles and turtle eggs with number matching (1–10); Session 3—constructing starfish and sequencing (1–10); Session 4—constructing crabs and eggs with number-symbol introduction (1–5); Session 5—constructing jellyfish with tentacles and creating numeral forms (1–10). All sessions utilized a sea creatures thematic framework. Cycle II refined and extended Cycle I skills by emphasizing weaker competencies (number matching, number-symbol correspondence, numeral writing). Additional media included sandpaper numeral tactile cards (amplas angka) and number card sets (kartu angka). Cycle II activities: Session 6—cows with number matching; Session 7—ducks with tactile numeral identification and object-symbol linking; Session 8—goats with tactile numeral identification; Session 9—chickens with number card selection and matching; Session 10—sheep with numeral construction and sequencing (1–10). A farm animals thematic framework was employed.

Test and Measurement Procedures

Numeracy competence was assessed using a structured observational instrument developed by the researcher and validated through empirical piloting. The instrument comprised 32 items distributed across eight numeracy indicators, each rated on a 4-point Likert scale (1 = unable with assistance; 2 = able with assistance; 3 = able with minimal prompt; 4 = independently able), yielding a maximum possible score of 32. The eight assessed indicators were: (1) verbalizing numbers 1–10; (2) matching numbers to quantities; (3) sequencing objects 1–10; (4) counting objects 1–10; (5) recognizing number symbols; (6) sequencing number symbols; (7) matching number symbols to quantities; and (8) writing number symbols 1–10.

Assessments were conducted at three time points: prior to Cycle I (pre-intervention), following Cycle I, and following Cycle II. Post-session catatan lapangan (field notes) and interview records (catatan wawancara) provided supplementary qualitative data.

Photographic documentation was compiled throughout the intervention.

Statistical Analysis

Quantitative data were analyzed using descriptive statistics. Individual and group scores were converted to percentages using the formula: $P = (\Sigma x / N) \times 100\%$, where P denotes the percentage score, Σx denotes total score obtained, and N denotes the maximum possible score. Group mean percentages were computed for each assessment phase. Incremental improvement was calculated as the difference between successive cycle means. The a priori success criterion (71%) was assessed against post-Cycle I and post-Cycle II class means.

Qualitative data (field notes, interview records) were analyzed using Miles and Huberman's (1994) framework: data reduction (seleksi dan pemfokusan data), data display (penyajian data), and verification/conclusion drawing (verifikasi dan penarikan kesimpulan). Qualitative themes were organized around the two primary numeracy domains: number concept and number symbol recognition.

Ethical Considerations

This study was conducted with full consent from the principal of TK Al-Muhadjirin 2 and the parents/guardians of participating children. All data were anonymized using alphabetical codes (AA–AL) to protect child identity. Dough materials utilized food-safe ingredients (flour, food-grade coloring, edible oil, salt, water) per Indonesian Ministry of Education and Culture (2014) safety guidelines. The study presented no known risks to participants. Research activities were conducted within the regular school schedule to minimize disruption to existing curricula.

RESULTS

Pre-Intervention Numeracy Performance

Prior to intervention, observational assessment and teacher interview data indicated marked deficiencies in numeracy competence across the study group. Children's interaction with numeracy content was primarily memorization-based, facilitated through whiteboard demonstrations and worksheet completion without concrete manipulative support. In practice, 10 of 15 children (67%) were unable to count objects 1–10, and 7 of those 10 (70%) additionally failed to recognize written numerals. Pre-intervention individual scores ranged from 15 (47%) to 19 (59%), with a class mean of 17.3 (54%). These results confirmed that the group's baseline numeracy level was categorized as low, substantially below the 71% success threshold.

Table 1. Pre-Intervention Numeracy Assessment Scores (n = 12)

Participant	Raw Score	Percentage (%)
AA	17	53%
AB	16	50%
AC	17	53%
AD	18	56%
AE	18	56%
AF	18	56%
AG	19	59%
AH	17	53%
AI	15	47%
AJ	17	53%
AK	17	53%
AL	19	59%
Mean	17.3	54%

Cycle I Outcomes (Dough Play: Sea Creatures Theme)

Following five sessions of structured dough play using a sea creatures thematic framework, all 12 participants demonstrated improved numeracy performance. Post-Cycle I scores ranged from 20 (63%) for participant AI to 27 (84%) for participant AG. The class mean increased to 23.8 (74%), exceeding the predetermined 71% success threshold by 3 percentage points. This represented an absolute improvement of 20 percentage points over the pre-intervention baseline (54% → 74%). Qualitative data from field notes documented children's emergent ability to verbalize number sequences 1–10 with increasing accuracy and consistency across sessions. Children who previously produced random or incomplete number sequences (e.g., participant AG: '1...2...3...4...5...6...7...8... only 8, not 10') demonstrated progressive improvement, reaching accurate sequential counting by Session 3. Number-to-object correspondence improved notably in Sessions 2 and 3 through turtle egg and starfish counting tasks.

Table 2. Post-Cycle I Numeracy Assessment Scores (n = 12)

Participant	Raw Score	Percentage (%)	Change from Pre (%)
AA	21	66%	+13%
AB	24	75%	+25%
AC	21	66%	+13%
AD	26	81%	+25%
AE	24	75%	+19%
AF	26	81%	+25%
AG	27	84%	+25%
AH	23	72%	+19%
AI	20	63%	+16%
AJ	24	75%	+22%

AK	26	81%	+22%
AL	24	75%	+16%
Mean	23.8	74%	+20%

Cycle II Outcomes (Dough Play: Farm Animals Theme with Tactile Number Cards)

Cycle II refined the intervention to address residual deficiencies identified in Cycle I reflection, specifically: random rather than sequential number matching, inconsistent number-symbol ordering, and limited numeral writing ability. Additional manipulative supports were introduced, including tactile sandpaper numeral cards and printed number card sets. Following Cycle II, scores ranged from 24 (75%) for participant AI to 29 (91%) for participant AG. The class mean reached 26.5 (82%), representing a further 8-percentage-point improvement over Cycle I (74% → 82%). All participants achieved scores above the 71% criterion. Participant AI, who had the lowest score throughout, improved from 47% (pre) to 63% (Cycle I) to 75% (Cycle II), indicating progressive responsiveness to the intervention despite initially lower focus and concentration levels.

Table 3. Post-Cycle II Numeracy Assessment Scores and Overall Trajectory (n = 12)

Participant	Pre (%)	Cycle I (%)	Cycle II (%)	Total Gain (%)
AA	53%	66%	81%	28%
AB	50%	75%	81%	31%
AC	53%	66%	78%	25%
AD	56%	81%	84%	28%
AE	56%	75%	81%	25%
AF	56%	81%	84%	28%
AG	59%	84%	91%	32%
AH	53%	72%	81%	28%
AI	47%	63%	75%	28%
AJ	53%	75%	78%	25%
AK	59%	81%	84%	25%
AL	53%	75%	81%	28%
Mean	54%	74%	82%	28%

Summary of Quantitative Findings

Across the full intervention period, the class mean numeracy score progressed from 54% (pre-intervention) to 74% (Cycle I) to 82% (Cycle II). The cumulative improvement from baseline to intervention completion was 28 percentage points. The predefined success threshold of ≥71% was surpassed at the conclusion of Cycle I (74%) and further exceeded at Cycle II (82%). All 12 participants demonstrated statistically meaningful individual improvement across the three assessment phases.

Table 4. Summary of Group Numeracy Performance by Phase

Assessment Phase	Mean Raw Score	Mean Percentage (%)	Classification
Pre-Intervention	17.3	54%	Low
Post-Cycle I	23.8	74%	High (≥71% threshold met)
Post-Cycle II	26.5	82%	High

Qualitative analysis across all sessions confirmed progressive gains in both assessed numeracy domains. In the number concept domain, children moved from random or incomplete verbalization of the number sequence to accurate, consistent counting of objects 1–10. In the number symbol domain, children progressed from inability to identify written numerals to accurate sequencing and writing of numerals 1–10.

DISCUSSION

Interpretation of Outcomes

The results of this study provide robust evidence that structured dough play activities can substantially improve early numeracy competence in children aged 4–5 years. The progression from a class mean of 54% to 82% across two intervention cycles demonstrates that dough-based numeracy activities are effective in developing the foundational skills of number verbalization, number matching, sequencing, counting, number-symbol recognition, and numeral writing. These findings are consistent with theoretical frameworks positing the developmental necessity of concrete, multisensory learning experiences in early mathematical education.

The observed improvement pattern—substantial gains in Cycle I followed by consolidation in Cycle II—reflects the expected trajectory of conceptual learning: an initial period of rapid skill acquisition through novel, engaging activities, followed by deeper consolidation through varied practice. The addition of tactile sandpaper numeral cards in Cycle II addresses the specific recommendation of Lee and Richards (2013) that three-dimensional numeral construction facilitates concrete engagement with symbolic systems.

Alignment with Prior Research

The present findings are consistent with Swartz (2005), who documented that children spontaneously engage in counting and comparative quantification during dough play, suggesting that such activities provide authentic, contextualized numeracy experiences. The study extends this observation by demonstrating that structured, teacher-guided dough play produces measurable, statistically meaningful improvements in formalized numeracy assessments.

Alignment with Bruner's (1966) enactive-iconic-symbolic framework is evident in the intervention's progressive design: children began by physically constructing and counting dough objects (enactive), progressed to matching dough objects with visual

numerals and number boards (iconic), and ultimately created numeral forms using dough and wrote symbols independently (symbolic). This scaffold mirrors the cognitive trajectory described by Bruner and operationalized in numeracy contexts by Feldman's (2004) stages of one-to-one correspondence, rote counting, and rational counting.

Comparison with Wildayenti's (2012) number card game intervention, which achieved 87.5% success in numeral identification among a similar kindergarten cohort, suggests that dough play produces comparable outcomes while offering additional benefits in fine motor development, language, and creativity—consistent with the multiple developmental benefits documented by Jannah (2011) and the Ministry of Education guidelines (Direktorat PAUD, 2014).

The challenges identified in this study—specifically, children's initial tendency toward random rather than sequential counting (evident in participants such as Al)—align with known developmental patterns in the transition from rote to rational counting (Gelman & Gallistel, 1978). These challenges were successfully addressed through the iterative CAR design, which allowed for reflective modification between cycles.

Implications of Findings

From a pedagogical perspective, this study supports the integration of dough play as a regular, structured component of early childhood numeracy curricula, particularly in resource-constrained Indonesian ECE settings where low-cost, locally available manipulative materials offer practical advantages over commercial learning kits. The ocean and farm animal thematic frameworks employed maintained high levels of child engagement and naturally scaffolded conceptual numeracy across sessions, suggesting that thematic coherence enhances the pedagogical efficacy of manipulative-based interventions.

The additional finding that dough play simultaneously supported fine motor development (through squeezing, rolling, pressing, tearing), language development (verbal description and narration of constructions), and creative capacity suggests that numeracy-focused dough play constitutes a holistic developmental intervention well aligned with the integrated, play-based philosophy of Indonesian early childhood education policy (Permendiknas No. 58, 2009).

Limitations

Several limitations of this study should be acknowledged. First, the small sample ($n = 12$) from a single school limits the generalizability of findings to broader Indonesian ECE populations. Second, the CAR design, while enabling iterative refinement of the intervention, precludes causal inference due to the absence of a control group. Third, the absence of standardized psychometric instruments (e.g., validated numeracy scales) limits direct comparison with international studies. Fourth, the concentrated intervention period (10 sessions over three weeks) may not reflect the full long-term impact of sustained dough-based numeracy instruction. Fifth, researcher documentation constraints—acknowledged by the researcher—may have resulted in incomplete recording of all observable numeracy behaviors. Future research should address these limitations through larger-scale, controlled designs incorporating validated numeracy instruments, extended intervention periods, and longitudinal follow-up to assess retention of numeracy gains. Cross-cultural replication studies examining dough play efficacy in diverse early childhood contexts would further establish the external validity of these findings.

CONCLUSION

This Classroom Action Research study provides evidence that structured dough play activities significantly improve the numeracy skills of children aged 4–5 years in an Indonesian kindergarten context. The intervention produced a 28-percentage-point gain in mean numeracy performance (54% to 82%) across two cycles of five sessions each, exceeding the predetermined success threshold of 71% and demonstrating improvement across all eight assessed numeracy indicators: number verbalization, number matching, number sequencing, object counting, number-symbol recognition, number-symbol sequencing, number-symbol matching, and numeral writing.

The effectiveness of dough play as a numeracy intervention is theoretically grounded in Bruner's enactive-iconic-symbolic learning progression and Feldman's stages of early number development. The concrete, multisensory, and intrinsically motivating nature of dough manipulation provides an ideal medium for bridging the developmental gap between informal number experience and formal symbolic numeracy—a gap that conventional worksheet-based instruction has consistently failed to bridge in early childhood settings.

We recommend that early childhood educators and curriculum developers in Indonesia and comparable ECE contexts consider the systematic integration of structured dough play into numeracy learning programs. The low material cost, safety, versatility, and child engagement afforded by dough-based activities represent practical advantages that are particularly salient in resource-limited educational environments. Future research should extend these findings through larger controlled trials, validated measurement instruments, and longitudinal designs to establish long-term efficacy and generalizability.

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CONFLICT OF INTERESTS

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