

## FFECT OF MONTESSORI MATHEMATICS INSTRUCTIONAL DELIVERY ON THE DEVELOPMENT OF EARLY CHILDHOOD NUMERACY SKILLS

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### Abstract

*This study examined the effect of montessori mathematics instructional delivery on the development of early childhood numeracy skills in Edo State, Nigeria. The study employed a mixed-methods design, combining quantitative data from a quasi-experimental approach with qualitative insights from classroom observations. A sample of 120 children aged three to five years and 10 early childhood educators were purposively selected from both Montessori and non-Montessori preschools across Esan West Local Government Area. Findings revealed that children exposed to Montessori instruction demonstrated significantly higher proficiency in number recognition, counting, sorting, patterning, and basic problem-solving compared to those in conventional classrooms. Moreover, qualitative data indicated that Montessori-trained teachers employed individualized teaching, concrete learning materials, and structured environments that encouraged active exploration, independence, and critical thinking. The results underscore the effectiveness of the Montessori Method in fostering foundational mathematical competencies during the early years of cognitive development. It recommends increased teacher training, curriculum reforms, and policy frameworks that support hands-on learning in the preschool setting*

**Keywords:** *Early Childhood Education, Mathematics Instruction, Montessori, Numeracy Skills, Preschool Learners*

### Introduction

Early Childhood Education (ECE) is globally recognized as the foundation for lifelong learning, academic success, and holistic development (UNESCO, 2021). Within this critical stage, the acquisition of numeracy skills, such as counting, number recognition, and simple arithmetic which eventually forms a core component of early learning outcomes. Numeracy, alongside literacy, equips children with essential tools to understand and interpret the world, particularly as it relates to logical reasoning, problem-solving, and cognitive development (Charlesworth & Lind, 2019; NAEYC, 2020).

In Nigeria, the early childhood education sector is gradually gaining prominence, following policy support from the education policy document of the Federal Republic of Nigeria (FRN) (2013), which emphasized the importance of Early Childhood Care, Development and Education (ECCDE). However, despite this growing attention, early numeracy achievement remains low in many Nigerian public and private Early Childhood Education centres, particularly in semi-urban and rural regions like Edo State (Okojie & Osagie, 2021). Factors such as Unqualified teaching personnel, improper use of instructional methods, inadequate supply of instructional materials, and overcrowded classrooms continue to hinder children's mastery of early mathematics (Aladejana, 2019; Nwachukwu, 2022).

Montessori education, pioneered by Maria Montessori in the early 20th century, offers an alternative, child-centered approach that emphasizes hands-on learning, using manipulative materials, individualized instruction, and a prepared environment conducive to exploration and discovery (Montessori, 1967; Lillard, 2017). Montessori mathematics instruction is particularly notable for its use of tactile materials like number rods, sandpaper numerals, and golden beads, which provide concrete representations of abstract mathematical concepts. These instructional tools help children develop numeracy skills through active study engagement, rather than rote memorization (Lillard, et al., 2013; Saracho, 2021).

Empirical evidence suggests that children in Montessori classrooms often outperform their peers in traditional settings, especially in areas such as problem-solving, mathematical reasoning, and executive functioning (Lillard et al., 2017; Okonkwo & Ezeanya, 2020). In Nigeria, a growing body of research indicates that when implemented correctly, the Montessori approach significantly enhances preschoolers' numeracy skills, fosters independence, and improves cognitive outcomes (Akinwale, 2020; Eze & Ofoha, 2020). However, few studies have domesticated this evidence within the specific socio-educational realities of Edo State.

Given the persistent gaps in early numeracy performance and the limited adoption of progressive instructional models in Nigerian classrooms, this study seeks to investigate the effect of Montessori mathematics instructional delivery on the development of early childhood numeracy skills in Edo State, Nigeria. By evaluating the effectiveness of this approach among preschool children in Esan West Local Government Area, of Edo State, Nigeria. The study aims to provide evidence-based recommendations for improving early childhood mathematics pedagogy delivery in Nigeria.

The purpose of this study is to explore and evaluate the effect of the Montessori mathematics instructional delivery on the development of early childhood numeracy skills, specifically, the study aims to:

1. Examine the mathematical concepts commonly introduced during early childhood education in Edo State.
2. Assess the application of Montessori teaching strategies in early childhood mathematics classrooms.
3. Determine the influence of Montessori materials and activities on children's cognitive development in numeracy.
4. Compare learning outcomes between Montessori and non-Montessori early childhood classrooms.

5. Provide recommendations for improving mathematics instruction at the early childhood level through Montessori principles.

### Research Questions

The study was guided by the following research questions:

1. What is the difference in mathematics achievement between children exposed to Montessori mathematics instruction and those taught using conventional methods in Edo State?
2. How does gender influence children's performance in early mathematics under Montessori instruction?
3. What are the perceptions of teachers on the use of Montessori materials in early mathematics teaching?

### Hypotheses

The following null hypotheses were formulated and tested at a 0.05 level of significance:

- **H<sub>01</sub>**: There is no significant difference in the mathematics achievement scores of children taught using Montessori instruction and those taught using conventional methods.
- **H<sub>02</sub>**: There is no significant gender difference in mathematics achievement among children taught using Montessori materials.
- **H<sub>03</sub>**: Teachers' perceptions of Montessori mathematics instruction do not significantly influence its effectiveness.

### Early Childhood Education

Early childhood education is the foundational stage of formal learning that spans from birth to the age of six. According to the education policy document of the FRN (2013), ECE in Nigeria is aimed at preparing children for primary education through a play-based, and holistic curriculum. During this phase, children develop essential skills in language, motor coordination, cognitive reasoning, and social interaction. ECE is especially significant for developing early mathematical thinking, as young children exhibit natural curiosity and problem-solving abilities that can be harnessed through guided exploration.

In Edo State, as in many parts of Nigeria, ECE is offered by both public and private institutions, with a growing awareness of the importance of preschool learning. However, disparities exist in the quality and methods of instruction across schools. Public preschools often suffer from poor funding, overcrowded classrooms, and untrained teachers, while some private schools incorporate globally recognized pedagogies like the Montessori method to varying degrees of fidelity.

### Early Mathematics Knowledge in Childhood Education

Early mathematics knowledge refers to the foundational and basic mathematical concepts introduced to young children, including number recognition, counting, sorting, patterning, shapes, measurement, and basic operations. Clements and Sarama (2011) argued that early mathematical knowledge is the strongest predictor of later academic success, even more than early reading skills.

Children in their formative years are capable of grasping abstract ideas when provided with concrete, hands-on experiences. The Nigerian early childhood curriculum encourages basic numeracy through rhymes, games, and play-based learning. However, in practice, many preschools employ rote memorization, worksheets, and didactic teaching, which may hinder genuine mathematical understanding and creativity.

## **Montessori Education and Mathematics Knowledge Acquisition**

The Montessori philosophy emphasizes learning through sensory experience, autonomy, and discovery. In mathematics, this is reflected in the use of specialized materials such as number rods, sandpaper numbers, spindle boxes, golden beads, and the decimal system board. These materials help children understand concepts like quantity, place value, and basic arithmetic by manipulating objects, thereby internalizing abstract ideas through physical interaction.

Montessori mathematics activities are presented sequentially and cater to the developmental readiness of the child. This contrasts with traditional approaches that often enforce uniform progression regardless of individual differences. In Edo State, some private schools offer modified Montessori program, although full implementation is rare due to cost, teacher training gaps, and parental preferences for exam-oriented methods.

## **Importance of Hands-On Learning in Mathematics**

Hands-on learning, a central tenet of Montessori, supports active participation and deep engagement. Piaget (1952) emphasized that children learn best through manipulation of physical objects. Montessori materials are designed to isolate one concept at a time, allowing focused learning. For instance, number rods teach length and sequence, while golden beads illustrate place value.

Such tactile experiences enhance memory retention, problem-solving, and independent thinking. In places such as Edo State, where classrooms do not have many resources, incorporating even improvised hands-on tools could significantly improve learners' understanding and interest in mathematics.

## **Theoretical Framework**

This study is hinged on two theories.

### **Montessori Theory of Learning (Maria Montessori, 1912)**

Maria Montessori's theory is based on the belief that children learn best in a prepared and resourceful environment that encourages exploration and independence. The following principles underpin Montessori mathematics education:

- Sensitive Periods: Children between ages 3–6 are particularly receptive to order, precision, and mathematical reasoning.
- Concrete to Abstract Progression: Learning begins with tangible materials and gradually shifts to symbolic representations.
- Control of Error: Materials are self-correcting, allowing learners to independently identify and resolve mistakes.
- Intrinsic Motivation: Montessori classrooms foster self-driven learning, enhancing persistence and curiosity.

In the context of this paper, the Montessori method serves as the experimental approach being evaluated for its effectiveness in early numeracy development.

## **Jean Piaget's Cognitive Development Theory**

Jean Piaget (1952) proposed that children move through stages of cognitive development: sensorimotor, preoperational, concrete operational, and formal operational. For early childhood (ages 2–7), the **preoperational stage** is most relevant. Children at this stage are:

- Egocentric but imaginative
- Limited in logical reasoning
- Reliant on concrete experiences to understand the world

Piaget’s theory supports the use of manipulative materials, visual aids, and guided play in early mathematics instruction. Montessori methods align well with Piaget’s views, emphasizing individualized, experiential learning.

### Research Design

This study adopted a quasi-experimental design using a pre-test–post-test control group approach. The quasi-experimental design is appropriate because it allows for the comparison between two groups—those exposed to the Montessori mathematics instruction (experimental group) and those taught with conventional methods (control group)—without random assignment.

The goal was to determine whether the use of Montessori instructional materials significantly improves early mathematics achievement among preschool children in selected early childhood education centers in Edo State, Nigeria.

### Population of the Study

The population of this study were comprised all children enrolled in Early Childhood Education Centres (Pre-K and Kindergarten levels) in Edo State, especially within the local government areas of Oredo, Egor, and Esan West, where both public and private early childhood institutions operate. Based on projections from the Edo State Ministry of Education (2024), the total number of enrolled children in formal early childhood centers across these three LGAs is approximately 18,000.

### Sample and Sampling Technique

A purposive sampling technique was used to select six early childhood education centers, three that use the Montessori method and three that use traditional methods. These schools were chosen based on the availability of trained teachers, use of instructional materials, and willingness to participate. A sample of B (60 in the experimental group and 60 in the control group), aged 4–6 years, was selected, using stratified random sampling to ensure equal and balance gender representation across the schools.

| Group            | No. of Schools | Total Pupils | Boys      | Girls     |
|------------------|----------------|--------------|-----------|-----------|
| Montessori Group | 3              | 60           | 30        | 30        |
| Control Group    | 3              | 60           | 30        | 30        |
| <b>Total</b>     | <b>6</b>       | <b>120</b>   | <b>60</b> | <b>60</b> |

### Instrumentation

Three instruments were used for data collection:

### Early Mathematics Achievement Test

This is a 20-item standardized test developed by the researcher, based on the Nigerian Early Childhood Education curriculum and aligned with Montessori mathematics concepts. The test

assesses number sense, counting, pattern recognition, sorting, and basic operations. It was administered as both a pre-test and post-test.

- **Reliability:** Piloted among 30 pupils in a non-participating school; Cronbach Alpha = .81.
- **Scoring:** Each correct item = 1 mark; total = 20 marks.
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### **Montessori Classroom Observation Checklist (MCOC)**

This checklist measured the fidelity of Montessori implementation in the selected experimental schools. It included items on:

- Use of standard Montessori materials
- Classroom organization
- Teacher-student interaction
- Independence in learning

Scoring was on a 3-point Likert scale (Not observed = 1, Partially observed = 2, Fully observed = 3).

### **Teacher Perception Questionnaire (TPQ)**

This 15-item structured questionnaire explored teachers' views on the usability, effectiveness, and challenges of Montessori materials in mathematics instruction. It used a 4-point Likert scale from Strongly Agree (4) to Strongly Disagree (1).

### **Reliability Analysis**

Cronbach's Alpha ( $\alpha$ ) = .77

To assess the internal consistency of the instrument used in this study, a pilot test was conducted. Reliability was measured using Cronbach's Alpha, a statistical coefficient commonly used to evaluate how well a set of items measures a single one-dimensional latent construct.

A Cronbach's Alpha value of .77 was obtained, indicating an acceptable level of internal consistency. According to widely accepted guidelines (e.g., George & Mallery, 2003), a Cronbach's Alpha of:

- $\geq .9$  is excellent
- $\geq .8$  is good
- $\geq .7$  is acceptable
- $\geq .6$  is questionable
- $< .6$  is poor

Therefore, with an alpha of .77, the instrument demonstrates sufficient reliability for further data collection and analysis.

### **Procedure for Data Collection**

1. **Pre-Testing:** EMAT was administered to both experimental and control groups before the intervention.
2. **Intervention Phase (6 Weeks):**

- The experimental group received Montessori mathematics instruction using appropriate materials (e.g., number rods, spindle boxes, sandpaper numbers).
  - The control group received conventional instruction (e.g., lecture-based, blackboard, counting with fingers or sticks).
3. **Classroom Observation:** Weekly observations were conducted to ensure the experimental group followed Montessori principles.
  4. **Post-Testing:** EMAT was administered again to both groups.
  5. **Teacher Survey:** TPQ was administered to 12 teachers (2 per school) at the end of the study.

### Method of Data Analysis

The data collected were analyzed using both descriptive and inferential statistics:

- **Research Question 1:** Mean and standard deviation were used to compare achievement scores between groups.
- **Research Question 2:** Independent t-test was used to examine gender differences.
- **Research Question 3:** Frequency counts and percentages were used to summarize teacher perceptions.
- **Hypotheses:**
  - **H<sub>01</sub> and H<sub>02</sub>:** Tested using independent sample t-tests.
  - **H<sub>03</sub>:** Tested using chi-square analysis for association between perceptions and classroom outcomes.

All analysis were conducted using SPSS version 25, and statistical significance was set at  $p < .05$ .

### Descriptive Analysis of Pre-Test and Post-Test Scores

The Early Mathematics Achievement Test (EMAT) was administered as both a pre-test and post-test to determine the effect of Montessori instruction on pupils' mathematics performance. Below is the summary:

**Table 4: Mean and Standard Deviation of Pre-Test Scores**

| Group                           | N  | Mean | SD   |
|---------------------------------|----|------|------|
| Experimental Group (Montessori) | 60 | 6.12 | 1.93 |
| Control Group (Conventional)    | 60 | 6.05 | 1.87 |

The pre-test scores for both groups were relatively the same, indicating that both groups started at comparable levels of mathematics understanding.

**Table 4: Mean and Standard Deviation of Post-Test Scores**

| Group                           | N  | Mean  | SD   |
|---------------------------------|----|-------|------|
| Experimental Group (Montessori) | 60 | 15.30 | 2.12 |
| Control Group (Conventional)    | 60 | 10.25 | 2.57 |

The experimental group showed a higher mean score in the post-test, suggesting a positive effect of Montessori instruction on early mathematics performance.

**Research Question 1:** What is the difference in mathematics achievement between children exposed to Montessori mathematics instruction and those taught using conventional methods?

**Table 4: Independent Samples t-Test Comparing Post-Test Scores**

| Variable                | Group        | Mean  | SD   | t     | df  | p-value |
|-------------------------|--------------|-------|------|-------|-----|---------|
| Mathematics Achievement | Montessori   | 15.30 | 2.12 | 11.23 | 118 | 0.000*  |
|                         | Conventional | 10.25 | 2.57 |       |     |         |

The p-value (0.000) is less than 0.05, indicating a **statistically significant difference** in performance between the two groups. Pupils taught using Montessori methods performed significantly better in mathematics.

**Research Question 2:** How does gender influence children’s performance in early mathematics under Montessori instruction?

**Table 4: Gender-Based Comparison in Montessori Group**

| Gender | N  | Mean  | SD   | t     | df | p-value |
|--------|----|-------|------|-------|----|---------|
| Male   | 30 | 15.10 | 2.24 | -0.79 | 58 | 0.435   |
| Female | 30 | 15.50 | 2.00 |       |    |         |

The p-value of .435 is greater than .05. This suggests that there is no significant gender difference in mathematics achievement under Montessori instruction.

**Research Question 3:** What are the perceptions of teachers on the use of Montessori materials in early mathematics teaching?

**Table 4: Summary of Teacher Perception Questionnaire (TPQ)**

| Item   | Strongly Agree | Agree | Disagree | Strongly Disagree |
|--|----------------|-------|----------|-------------------|
| Montessori makes learning more engaging                  | 9              | 3     | 0        | 0                 |
| Children learn better with hands-on materials            | 10             | 2     | 0        | 0                 |
| Montessori tools help in concept retention               | 8              | 4     | 0        | 0                 |
| Time-consuming to prepare lessons using Montessori tools | 2              | 4     | 4        | 2                 |
| Requires specialized training to use effectively         | 6              | 5     | 1        | 0                 |

**Interpretation:** Teachers generally hold **positive perceptions** toward Montessori instruction in early mathematics. Most agree that it promotes engagement and concept retention. However, there are concerns about time and the need for specialized training.

#### 4.5 Hypotheses Testing

##### Hypothesis One ( $H_{01}$ ):

There is no significant difference in the mathematics achievement scores of children taught using Montessori instruction and those taught using conventional methods.

- **Decision:** Reject  $H_{01}$  because  $p < 0.05$ .
- **Conclusion:** Montessori instruction significantly improves early mathematics achievement.

### Hypothesis Two (H<sub>02</sub>):

There is no significant gender difference in mathematics achievement among children taught using Montessori materials.

- **Decision:** Do not reject H<sub>02</sub> because  $p > 0.05$ .
- **Conclusion:** Gender does not significantly influence mathematics performance under Montessori instruction.

### Hypothesis Three (H<sub>03</sub>):

Teachers' perceptions of Montessori mathematics instruction do not significantly influence its effectiveness.

Chi-square analysis:

| Variable                                 | $\chi^2$ | df | p-value |
|--|----------|----|---------|
| Teacher Perception × Pupils' Performance | 10.74    | 4  | 0.030*  |

- **Decision:** Reject H<sub>03</sub> because  $p < 0.05$ .
- **Conclusion:** Positive teacher perception is significantly associated with the successful implementation of Montessori mathematics instruction.

### Discussion of Findings

The study investigated the effect of Montessori mathematics instruction on early childhood pupils' mathematics achievement in Edo State, Nigeria. The findings support previous literature on the value of child-centered, hands-on learning environments in fostering cognitive development, especially in the formative years.

### Montessori Instruction and Mathematics Achievement

The analysis revealed that children who were taught using Montessori methods significantly outperformed their counterparts in the conventional classroom. This aligns with the findings of Lillard (2017) and Saracho (2021) who emphasized the cognitive benefits of self-paced, manipulative-based learning in early childhood education. The post-test mean score of 15.30 in the experimental group compared to 10.25 in the control group confirms that Montessori pedagogy enhances pupils' ability to grasp abstract mathematical concepts through concrete experiences. This result is particularly important in Edo State where early childhood education is still evolving. The use of beads, number rods, golden beads, and other tactile materials creates an immersive and exploratory learning environment, enabling young learners to internalize mathematical ideas effectively.

### Gender and Mathematics Achievement under Montessori Instruction

The analysis found no significant difference in the mathematics performance of boys and girls exposed to Montessori methods. This supports the assertions by Charlesworth and Lind (2019) that Montessori education reduces gender disparities in academic outcomes by allowing each child to progress at their own pace. It also validates the observation by Adeyemi and Oyetade (2022) that learning style, rather than gender, is a more significant predictor of achievement in Nigerian classrooms. In the context of Edo State, where traditional biases sometimes favor male academic superiority, these findings reinforce the importance of inclusive teaching strategies that equalize opportunities across gender lines.

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## Teacher Perceptions and Effective Use of Montessori Materials

Teachers generally held favorable views toward the use of Montessori instructional strategies. Many of them observed that the materials made learning more engaging and improved retention of concepts. However, a few expressed concerns about the time required for preparation and the need for specialized training. These concerns align with observations made by Eze and Ofoha (2020), who noted that although Montessori methods are effective, inadequate teacher training and lack of infrastructure remain challenges in Nigerian early childhood settings.

Positive teacher attitudes were significantly associated with successful outcomes, emphasizing the critical role of teacher belief systems in the implementation of any pedagogical innovation.

### Conclusion

The study concluded that Montessori mathematics instruction significantly enhances early childhood pupils' understanding and achievement in mathematics in Edo State. It offers an inclusive and gender-neutral approach to learning, catering to diverse learners regardless of background or cognitive style.

Key takeaways include:

- Montessori instruction yields better mathematics outcomes than conventional methods.
- Gender does not influence performance when children are exposed to Montessori learning.
- Teacher perception strongly influences the effectiveness of Montessori instruction.

Given the findings, Montessori instruction represents a promising alternative to conventional teaching in early mathematics, particularly in the formative years where conceptual understanding is foundational.

### Implications for Early Childhood Education in Edo State

1. *Policy Development:* The State Ministry of Education should revise its early childhood education curriculum to incorporate elements of the Montessori approach, especially in mathematics instruction.
2. *Teacher Training:* Continuous professional development programs should be established to train early childhood educators in Montessori philosophy and practice.
3. *Infrastructure:* Investment should be made in developing Montessori classrooms with age-appropriate manipulatives to foster effective learning environments.
4. *Parental Engagement:* Awareness campaigns should be introduced to educate parents on the benefits of Montessori methods to ensure home-school collaboration.

### Recommendations

1. *Adoption of Montessori Methods:* Schools across Edo State should integrate Montessori strategies into their early childhood mathematics programs to enhance pupils' academic outcomes.
2. *Capacity Building:* Government and private institutions should organize workshops and seminars to train educators on how to effectively implement Montessori tools and strategies.
3. *Monitoring and Evaluation:* The State Universal Basic Education Board (SUBEB) should establish monitoring teams to evaluate the effectiveness of Montessori integration and provide support where needed.
4. *Curriculum Reform:* Curriculum developers should revise the early childhood mathematics curriculum to reflect experiential learning principles embedded in the Montessori philosophy.

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5. *Resource Provision:* Stakeholders should ensure that adequate Montessori materials are provided to schools, especially in rural areas of Edo State.

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