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# THE EFFECT OF USING MANIPULATIVES ON THE PERFORMANCE OF PUPILS IN PRIMARY SCHOOL MATHEMATICS

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## Abstract

This paper investigates the effects of using manipulatives on the performance of pupils in primary school mathematics. The study followed a quasi-experimental research design involving two equivalent groups: the control group and an experimental group each comprising 40 pupils. Pretest-Posttest Mathematics Achievement Tests (PPMAT) were developed for this study. The instruments were pilot-tested and a reliability coefficient of 0.79 was obtained. The data collected were analyzed using SPSS. Teaching must be interactive, illustrative, exploratory, and student-centered. In monolingual cultures, English becomes the progressive language of teaching in the fourth year, whereas in the first three years, education is conducted in the language of the immediate area. Children are active learners who grasp concepts by moving through three stages of knowledge: concrete, representational, and abstract, according to the learning theory of psychologist Jean Piaget. The results of this study imply that manipulatives have positive effects on the performance of pupils in mathematics. It is recommended that manipulatives should be used as much as possible to better the mathematics performance of pupils in primary school. This points to the fact that conceptual knowledge founded in a direct relationship of the mathematical process with necessary manipulatives is essential to build appropriate hands-on experiences to apply learning to new contexts. Students are taking the essential first steps toward developing an understanding and internalizing mathematical processes and procedures when they manipulate objects themselves. The use of manipulatives enables pupils to explore the mathematics process at the concrete level of understanding through representational and finally to the abstract level.

**Keywords**: *Mathematics, Primary, Pupils, Performance, Manipulatives.*

## Introduction

People from many different cultures have employed artifacts to aid with their daily math difficulties from the dawn of time. The Middle East and Southwest Asia ancient civilizations employed counting boards. These were trays made of clay or wood that were lightly dusted with sand. To take an inventory or total an account, for instance, the user would draw symbols in the sand. The first abacus was made by the ancient Romans by altering counting boards. It's possible that the Chinese abacus, which was used centuries later, was a modification of the Roman abacus. In the Americas, comparable devices were also created (Ruzic & O'Connell, 2001). Both the Mayans and the Aztecs used counting implements that consisted of wires or maize kernels strung on a thread and laid across a wooden frame. Quipu, a type of string used as a counting aid, was a distinctive invention of the Incas. The first true manipulatives, or maneuverable devices that engage several senses and are created particularly to teach mathematical ideas, were created in the late 1800s. To help his kindergarten students discover patterns and appreciate geometric forms seen in nature, Friedrich Froebel, a German educator who established the first kindergarten program in the world in 1837, created a variety of objects. Maria Montessori, an Italian-born educator, furthered the notion that manipulatives are crucial in teaching in the early 1900s. She created a variety of products to aid pupils in learning mathematics and other fundamental concepts in preschool and primary school. According to Ruzic and O'Connell (2001), kids who regularly use manipulatives perform better academically because they can observe, model, and assimilate abstract ideas through the use of concrete items.

## 2. Review of Related Literature

### 2.1 Primary Education

Children aged 6 to 12 receive quality, universally required, and free primary education. Teaching must be interactive, explicative, experimental, and kid-centered (Abbas & Muhammad, 2015). For the first three years, education is conducted in the language of the immediate area. In monolingual societies, English takes over as the progressive language of teaching in the fourth year. At a teacher-to-student ratio of 1:35, elementary school mathematics is taught by an expert in the subject. Children are active learners who grasp concepts by moving through three stages of knowledge: concrete, representational, and abstract, according to learning theory based on psychologist Jean Piaget (Muhammad & Garba, 2014). Students can investigate ideas at the initial, or concrete, level of comprehension by using manipulatives. Students are taking the crucial first steps toward developing an understanding and internalizing mathematical processes and procedures when they manipulate objects. For instance, students can symbolize each added fraction using fraction strips when learning to add fractions. The sum is then calculated by adding the fractional components. They can move on to determining sums for problems on paper by representing equivalent fraction numbers after practicing with these (representational level). Over time, they will develop methods and use algorithms to be able to calculate sums when just given the addition statement (abstract level).

#### 2.1.1 Objectives of Primary Education in Nigeria

The objectives of primary education according to the National Policy on Education (NPE, 2013) are to:

i. Inculcate permanent literacy, numeracy, and the ability to communicate effectively.

ii. Lay a sound basis for scientific, critical, and reflective thinking.

iii. Promote patriotism, fairness, understanding, and national unity.

iv. Instill social, and moral norms and values in the child.

v. Develop in the child the ability to adapt to the changing environment.

vi. Provide an opportunity for the child to develop live manipulative skills that will enable the child to function effectively in society within the limits of the child's capability.

### 2.2 Definition of Manipulatives

Larbi & Marvins (2016), describes manipulatives as objects that appeal to several senses and that can be touched, moved about, rearranged, and otherwise handled by children. Manipulatives are actual objects that are used as teaching aids in mathematics classes to include students in hands-on learning. They can be applied to clarify, practice, or introduce concepts. A manipulative is a piece of equipment created so that a learner can use it to manipulate some mathematical idea to understand it. Children can learn topics through developmentally appropriate hands-on experience by using manipulatives. During the second half of the 20th century, the use of manipulatives in mathematics courses around the world saw a significant increase in popularity (Agujar, 2018). In the first stage of teaching mathematical concepts, concrete representation, and mathematical manipulatives are usually utilized. The second and third steps, respectively, are representational and abstract. Rice grains are a straightforward example of a mathematical manipulative, while a model of the solar system is more complex. They could be made by teachers or students, purchased from a store, or brought from home.

Throughout the second half of the 20th century, the use of manipulatives in mathematics courses around the globe increased in popularity significantly. In addition to allowing students to create their mental models of abstract mathematical concepts and operations, manipulatives also give them a common language to express these models to teachers and other students (Moore, 2014). The use of manipulatives also has the added benefit of keeping pupils interested in arithmetic and making it more enjoyable for them. Students say they are more interested in mathematics when given the chance to use manipulatives. Increased mathematical competence is correlated with long-term mathematical interest (Sutton & Krueger, 2002). Students can improve their mathematical thinking skills by using manipulatives. According to Stein and Bovalino (2001), "Manipulatives can be important tools in helping students to think and reason in more meaningful ways. By giving students concrete ways to compare and operate on quantities, such manipulatives as pattern blocks, tiles, and cubes can contribute to the development of well-grounded, interconnected understandings of mathematical ideas". The use of manipulatives, following Agujar (2018), aids students in grasping mathematical ideas and the reversibility of mathematical operations.

### 2.3 Importance of Manipulatives in Mathematics Classrooms

Sebesta and Martin (2004) pointed out that with long-term use of manipulatives in mathematics classrooms, educators have found that students make gains in the following general areas:

i. Verbalizing mathematical thinking

ii. Discussing mathematical ideas and concepts

iii. Relating real-world situations to mathematical symbolism

iv. Working collaboratively

v. Thinking divergently to find a variety of ways to solve problems

vi. Expressing problems and solutions using a variety of mathematical symbols

vii. Making presentations

viii. Taking ownership of their learning experiences

ix. Gaining confidence in their abilities to find solutions to mathematical problems using methods that they come up with themselves without relying on directions from the teacher

### 2.4 Guidelines for the use of Manipulatives

According to Bouck, Satsangi, and Park (2018), the following are the guidelines for the use of manipulatives:

i. The manipulatives must support the lesson's objectives.

ii. The manipulatives must accurately illustrate the actual mathematical process being taught.

iii. More than one manipulative should be used to introduce a process.

iv. The manipulative must involve moving parts or be something that is moved to illustrate a process.

v. Orient students to the manipulatives and corresponding procedures.

vi. Plan for the use and fading out of manipulatives as students gain an understanding of the concept.

vii. Learning comes not from the object themselves, but from the student's physical actions with the objects.

viii. The manipulative must be used individually by each student.

ix. A direct correlation must exist between the process illustrated by the manipulative and the process performed with pencil and paper.

x. Assist students in building self-monitoring skills (e.g., teach them how to learn)

## 2.5 Manipulatives for Mathematics Instructions

The understanding and development of young children in mathematics are greatly aided by the use of mathematical manipulatives. These tangible artifacts help kids comprehend key mathematical notions and eventually assist them in connecting these concepts to illustrations and abstract concepts. There are also Geoboards, pattern blocks, fraction strips, number lines, and interlocking cubes (Allsopp, 2006; Krech, 2000; Stein & Bovalino, 2001; Van de Walle & Lovin, 2005).

i. Number lines: A number line is a straight line with numerals arranged at equal segments or intervals throughout its length. A number line is often shown horizontally and can be extended indefinitely in any direction. Moving from left to right raises the numbers on the number line while moving from right to left decreases them. To add, count on, remove, multiply, skip a count.

ii. Fraction strips: Fraction strips are small, colored pieces of paper that are rectangular and used to teach fractions. Fraction strips are used to recognize equivalent fractions, illustrate portions of a whole, and identify fractions.

iii. Pattern blocks: These are small blocks that are frequently used as educational materials in classrooms. They are typically composed of either wood or plastic. Green triangles, orange squares, blue rhombuses, beige narrow rhombuses, red trapezoids, and yellow hexagons are always included in a set of pattern blocks.

iv. Interlocking cubes: Using interlocking cubes gives students a hands-on opportunity to recognize, develop, and create mathematical patterns. They can be used to practice addition, subtraction, and multiplication skills in addition to simple counting and sorting. Additionally, they help with fraction visualization.

v. Geoboards: A mathematical tool called a geoboard is used to examine fundamental ideas in plane geometry, such as perimeter, area, and the properties of triangles and other polygons. Geoboards are made of a physical board with a particular number of half-driven nails and rubber bands wrapped around them.

vi. Coins, beads, buttons, etc.: Coins may be used by students to develop their money management abilities, but beads and loose buttons can also be a pleasant approach to encourage all types of learning.

## 2.6 Number Line

Number lines are a key concept that begins to be used in primary 2 to help pupils learn about the organization of the number system and the basic operations of addition, subtraction, and multiplication. The number line has been one of mathematics' more significant "inventions". Ancient Egyptians are credited with creating a very useful number line around 2,500 years ago. They made equal-distance knots along a rope that was used to gauge length by counting the spaces between each knot. Egyptian rope measurers have drawn a triangle with 3, 4, and 5 spaces along each side in the image. Since the rope was one continuous length, it could be used to gauge fields, barriers, or construction sites. The rope was an effective visual aid that paired well with actual objects. Both measurements and calculations involving "straightforward" operations like addition and multiplication benefited from its use. John Wallis, an Englishman, is typically credited with inventing the number line, which was used to display numerals less than 0. He utilized a solid line for 0 and the positive numbers in his early illustrations, and a dotted line for the negative numbers.

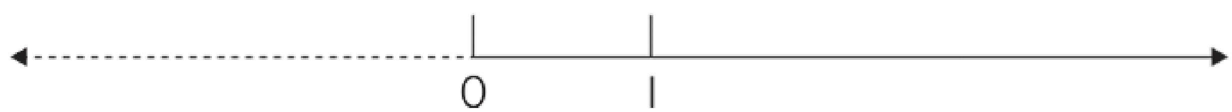


**Figure 1:** Number line showing negative, zero, and positive numbers

The number line is shown in Figure 1 above, with the solid line representing the percentage of ongoing positive numbers and the dotted lines representing the percentage of ongoing negative numbers. Descartes, a Dutch mathematician, developed the x-y coordinate system about the same period by using two lines, which helped to support Wallis' methodology (Sutton & Krueger, 2002). Number lines were a useful tool for linking all numbers together as well as for displaying negative values. With the help of these tools, it was possible to manipulate numbers using just one visual model, which allowed for great advancements in the exploration of new mathematical concepts.

A number line is a representation of an abstracted graduated straight line for real numbers. It is assumed that each real number and each point on a number line relate to one another (Stewart, Redlin & Watson, 2008). The integers are frequently represented as specially designated, uniformly spaced dots on a line. The line includes all real numbers, going eternally in both directions, even though this image only displays the integers from -9 to 9, as well as the numbers that are in between the integers. In particular, when teaching simple addition, subtraction, and multiplication with negative numbers, it is frequently used as a manipulative.

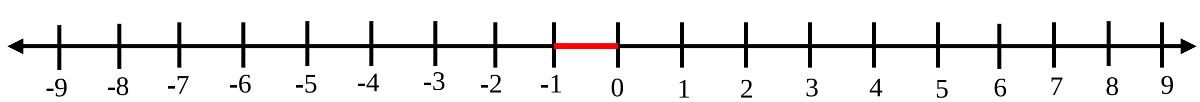


**Figure 2:** Number line showing the integers from $-9$ to 9

The number line, which is typically depicted as horizontal, is shown in Figure 2. In addition, arrowheads on either end of the line are intended to show that the line extends endlessly in both positive and negative directions. Positive numbers always lay on the right side of zero, whereas negative numbers always lie on the left side of zero. It is customary to just use one arrowhead to represent the direction that numbers increase (Stapel, 2015). According to the laws of geometry, a line without endpoints is an endless line, a line with one endpoint is a ray, and a line with two endpoints is a line segment. The line continues indefinitely in both the positive and negative directions.

### 2.7 Skip-counting

The number line is seen in Figure 2 and is typically shown as being horizontal. The arrowheads on either end of the line indicate that the line extends forever in both positive and negative directions. Positive numbers always lie on the right side of zero, while negative numbers always lie on the left side of zero. Typically, only one arrowhead is used to represent the direction in which those numbers increase (Stapel, 2015). The line extends endlessly in both the positive and negative directions following the laws of geometry, which classify a line without endpoints as an infinite line, a line with a single endpoint as a ray, and a line with two endpoints as a line segment. Two numbers can be multiplied as in this example: To multiply $2 \times 3$, note that this is the same as $2 + 2 + 2$, so pick up the length from 0 to 2 and place it to the right of 2, and then pick up that length again and place it to the right of the previous result. This gives a result that is 3 combined lengths of 2 each; since the process ends at 6, we find that $2 \times 3 = 6$. Skip counting is the term used to describe this procedure. Skip counting gives a solid basis for number sense, visualization, and applications while assisting pupils in recognizing patterns in numbers. The gradual process of skipping the same measure (place) of a number on the number line is referred to as skip counting. The multiplication table of a given number is often produced by skipping the same measure on the number line:

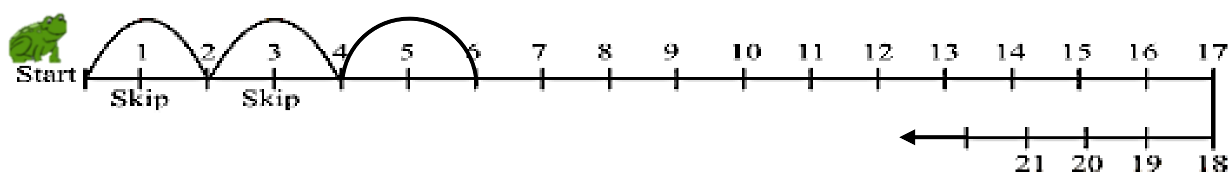


**Figure 3:** Skip counting on the number line

A frog can be seen moving along the number line in Figure 3. The frog advances along the number line, skipping the same measure (place) of number(s), with zero (zero) being the origin. Starting at 1, it skips one position before resting on 2, then skips one position from 2 again to skip 3 and rest on 4, then skips the same position from 4 again to rest on 6. This sample constructs the multiplication table of two by skipping one place. Similar to how skipping 2 places would result in the multiplication table of 3, skipping 4 places would result in the multiplication table of 5. To help students create the multiplication table of 2 on the number line, Figure 3 offers some guidance for teachers. The first step that students must take to develop an understanding and internalize mathematical processes and procedures is being taken at this point (Concrete level). Following practice with these, they can move on to the second step (representational level), where they can create the multiplication tables of various numbers on paper. Over time, at the abstract level, they will develop strategies and apply algorithms to create the multiplication tables for "n" terms by skipping counting (n-1) places on the number line beginning at zero.

## 3. Methodology

The study followed a quasi-experimental research design involving two equivalent groups: the control group and an experimental group each comprising 40 pupils. Pupils in the experimental group were taught mathematics using manipulatives to enable the effect in the teaching and learning to be examined. The subjects for this study were 80 primary four (4) pupils purposively sampled from the Polytechnic Staff Academy of Waziri Umaru Federal Polytechnic Birnin Kebbi. The choice of this school was influenced by factors such as time constraints, cost implications, and also the subject's convenience during festivities. Pretest-Posttest Mathematics Achievement Tests (PPMAT) were developed for this study. The instruments were given to experts for face, content, and construct validity. The instruments were then pilot-tested in a primary school that is part of the population but not part of the sample. The reliability coefficient of the instrument was 0.79 which is suitable for use (Sani, 2017).

Before the treatment, the pretest was conducted to determine homogeneity and the results showed no significant difference between the two groups. The pupils in the experimental group were taught basic operations of addition, subtraction, and division using manipulative (number lines) whilst pupils in the control group were taught without any manipulative. The posttest was conducted after 4 weeks of treatment to determine the impact the use of the number line has on learners. The data collected were analyzed using SPSS (version 24).

## 4. Results and Discussion

**Table 1:** t-test Comparing Pretest Scores of Experimental and Control Groups

| *Groups* | *N* | $\bar{X}$ | *SD* | *df* | *t* | *Sig.* |
|---|---|---|---|---|---|---|
| *Experimental* | 40 | 12.39 | 2.07 | 78 | 0.359 | 0.752 |
| *Control* | 40 | 12.48 | 2.19 | | | |

The findings in Table 1 reveal no significant difference between the experimental and control groups in the pretest scores; [$t(78) = 0.359$, $p > 0.05$]. based on this analysis, both groups (experimental and control) are considered the same and equivalent (homogenous).

**Table 2**: t-test Result for Posttest

| *Groups* | *N* | $\bar{X}$ | *SD* | *Df* | *t* | *Sig.* |
|---|---|---|---|---|---|---|
| *Experimental* | 40 | 25.85 | 3.48 | 78 | 8.975 | 0.001 |
| *Control* | 40 | 19.35 | 2.89 | | | |

The findings in Table 2 show the performance of both groups in the posttest. It can be seen that the performance of pupils in the experimental group significantly increase more than the performance of pupils in the control group [$t(78) = 8.975$, $p > 0.05$]. This implies that the use of number lines has a positive impact on pupils' performance in primary school mathematics. On the contrary, pupils taught without the use of any manipulative did not yield a satisfactory result. The results are in agreement with Jean Piaget's theory of learning, which suggests that the first step of internalizing mathematical processes requires conceptual understanding rooted in the direct linkage of mathematical processes with appropriate manipulatives. This understanding might encourage and enable pupils with different abilities to develop appropriate hands-on experiences necessary to apply learning to new situations. Additionally, the results are consistent with the goals of primary education in Nigeria.

## 5. Conclusion

The following conclusions were drawn based on the findings of the study

i. The use of number lines significantly increases the performance of pupils in the experimental group unlike their counterparts in the control group.

ii. Primary school pupils taught using manipulatives performed better in mathematics than those taught without manipulatives.

## 6. Recommendations

The following recommendations were made:

i. Teachers should use manipulatives as much as possible for effective teaching and learning of all mathematical concepts in primary school.

ii. Teachers should do more on the maintenance and development of manipulatives crucial for comprehending essential mathematical processes in primary school.

iii. The government needs to establish and oversee rules for the use and manufacture of manipulatives suitable for all educational levels.

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