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An Investigation of the Use of Physical Manipulatives to Enhance the Conceptual Understanding of Operations on Fraction Among Pre-Service Teachers

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ABSTRACT: *This study aimed to investigate the role of physical manipulatives in building pre-service teachers' conceptual understanding of fractions. Using a quasi-experimental design, one hundred fifty (150) pre-service teachers were chosen based on purposive sampling. Before implementing the five-week intervention design, which was based on manipulatives, an initial test was conducted. To collect additional data for the study, a second test was administered immediately after the intervention to supplement the pre-intervention test. The statistical analysis revealed a Pretest (mean = 9.11, standard deviation = 4.863), and a Post-test (mean = 21.60, standard deviation = 6.021). The null hypothesis was rejected using the t-test, which revealed ($P = 0.00 < 0.05$) at a confidence level of 95%, as there was a statistically significant difference in the performance of Pre-service teachers between the two tests. Therefore, the researchers recommend that fractions be taught using manipulatives in colleges of education.*

KEYWORDS: Physical manipulatives, procedural competency, pretest-posttest design, multisensory

INTRODUCTION

Mathematics has been identified as a subject that fosters the development of creative, innovative, analytic, and problem-solving abilities (NaCCA, MOE, 2019). Consequently, it constitutes the core curriculum for Basic and Secondary school education in most countries (OECD, 2021). After Ghana's independence, the government has made concerted efforts to train teachers with the ability to inspire learning. The government, in collaboration with various stakeholders such as the Ministry of Education (MOE), Ghana Education Service (GES), and Transforming Teacher Education and Learning (T-TEL), runs workshops and enrichment programmes to improve the knowledge and skills of in-service teachers. The government has also subsidised the fees for in-service teachers who voluntarily enrol in Distance Education and Sandwich courses to further their education.

The current mathematics curriculum in Ghana emphasises the 4Rs (NaCCA, MOE, 2019) to enable children to reach their full potential in mathematics. Reading, writing, arithmetic, and creativity are the 4Rs for all students. It is expected that all students will possess these foundational skills. (Baah-Duodu et al., 2020) Noted that mathematics should be taught using hands-on and minds-on methods that students find enjoyable and adopt as a lifestyle. The ability of teachers to adhere to this routine would ensure that students can think, reason, and communicate mathematically. Consequently, mathematics lessons must engage students in real-world problem-solving activities through group work and classroom discussions (Adu et al., 2017).

Understanding fractions is one of the essential mathematical skills to develop. This is because it is essential for understanding algebra, geometry and other aspects of mathematics. Understanding fractions means understanding all the possible concepts that fractions can represent (Bingham & Rodriguez, 2019). A fundamental understanding of fractions is essential for any high school student to be able to handle more advanced topics (Niemi, 1996). Fractions have a significant role in algebra, geometry, probability, and trigonometry, amongst others. According to Furner and Berman (Brashier et al., 2014), the NCTM curriculum and Evaluation Standards (1989) encourage the use of physical materials and other representations to aid in the development of learners' fraction concept understanding.

Significant evidence suggests that the effective use of visuals in fraction tasks is crucial (Agyei et al., 2022; Bouck & Park, 2018; Cramer & Henry, 2002). Sadly, textbooks rarely include Manipulatives, and when they do, they are typically limited to area models (Hodges et al., 2008; Yeo & Webel, 2022). Students frequently need more opportunities to explore fractions with various models and the time to connect the visuals to the related concepts. The use of physical tools leads to the development of mental models, which strengthens students' understanding of fractions (Cramer & Whitney, 2010; Lee et al., 2021). Utilised correctly, manipulatives can help students clarify concepts that are frequently muddled in a purely symbolic model. Sometimes it is beneficial to conduct the same activity with different representations and ask students to draw connections between them. Different representations provide students with varied learning opportunities.

Historically, the teacher has been the classroom's leader. The teacher's responsibilities included working from the front of the classroom, dispensing information on the day's topic, and assigning homework. However, in the ever-changing world of mathematics, this function is evolving. Cain-Caston states that the teacher is now the observer while the students actively engage in their learning (Bingham & Rodriguez, 2019). In most classrooms across the globe, including Ghana, mathematics class has evolved from a tedious pencil-and-paper chore to a fun and exciting activity that many children now anticipate. The same concepts are being taught, but it has become more of a pleasure than a chore. What has caused the change? According to studies, the answer is using manipulatives and a hands-on learning technique.

In the context of education, manipulatives refer to the use of visual and physical tools such as coins, blocks, puzzles, and markers for teaching (Bouck & Park, 2018). The purpose of manipulatives is to enable students to practise, interact, and manipulate materials and resources in order to find solutions to problems. The use of manipulatives dates back to ancient times (Caglayan & Nikiforidou, 2019), and people from various ancient civilisations have used physical objects to solve common mathematics problems. For example, Southwest Asia (the Middle East) utilised counting boards, wooden or clay trays with a thin layer of sand covering them. The user would draw symbols in the sand to count, for instance, an account or inventory. Ancient Romans modified counting boards to create the first abacus (Boakye, 2019). The Chinese abacus, developed centuries later, may have evolved from the Roman abacus. Comparable devices were created in the Americas. Both the Mayans and the Aztecs utilised counting devices consisting of corn kernels strung on string or wires and stretched over a wooden frame. The Incas had their unique counting tool, quipu, consisting of knotted strings. In the late 1800s, the first actual Manipulatives were created; these are multisensory, manipulable objects specifically designed to teach mathematical concepts (Bartolini & Martignone, 2020). Friedrich Froebel, a German educator who founded the world's first kindergarten programme in 1837, created various objects to help his kindergarten students recognise patterns and appreciate geometric shapes found in nature.

Early in the 20th century, Italian-born educator Maria Montessori promoted the importance of manipulatives in education. She created numerous materials to assist preschool and elementary school students in discovering and learn fundamental math and other subject concepts. Since the early 1900s, manipulatives have been considered indispensable for teaching mathematics in elementary schools. The National Council of Teachers of Mathematics (NCTM) has recommended manipulatives for teaching mathematical concepts at all grade levels for several decades (Jimenez & Stanger, 2017; Sulistyaningsih et al., 2017). By providing students with concrete means of comparing and manipulating quantities, manipulatives such as pattern blocks, tiles, and cubes can aid in the development of solid, interconnected understandings of mathematical concepts. Utilising Manipulatives effectively can aid students in connecting ideas and integrating their knowledge, thereby enhancing their comprehension of mathematical concepts. Teachers play a crucial role in facilitating students' use of Manipulatives so that they can navigate all three stages of learning and develop a solid grasp of mathematical concepts.

Experiential learning theory, for instance, is predicated on the notion that knowledge acquisition is enhanced when students engage in active processes (Black et al., 2021; Dowling et al., 2018). Mathematical instruction can be more effective, dynamic, and engaging through manipulatives. Manipulatives facilitate student learning by transitioning from concrete experiences to abstract reasoning (Agyei et al., 2022; Satyam & Aithal, 2022). According to education specialists, this learning occurs in three stages. These are the cognitive, associative, and autonomous stages of development (Wright, 2018, 7 November). Manipulatives have been established in the literature as an essential tool for teaching mathematics because it makes mathematics concepts accessible to almost all learners and is particularly useful for teaching low achievers and students with learning disabilities (Jimenez & Stanger, 2017). Research has shown that manipulatives improve students' communication skills at study levels. Working with Manipulatives deepens understanding of all mathematical concepts, particularly fraction concepts, because it provides visual representations of ideas, assisting students in identifying and comprehending the concept of fractions and leading to retention and application of information to new problem-solving situations (Shaw, 2002). Again, according to Shaw (2002), using Manipulatives to teach fraction concepts is a way to address students' misconceptions about fractions. Additionally, through the use of Manipulatives, students actively construct conceptual knowledge.

Intriguingly, numerous local studies have validated the use of manipulatives as one of the most effective methods for teaching mathematics (Bouck & Park, 2018). Students still struggle with fraction operations (addition, subtraction, division, and multiplication), notably addition and subtraction of unlike denominators. Sometimes, students add/subtract the numerators and denominators separately, then write the results as numerator and denominator, as opposed to first equating the denominators and then adding them (Lee et al., 2021; Namkung et al., 2018; Yeo & Webel, 2022). The majority of studies in this field were conducted with classroom students. As far as we know, investigations involving Pre-service teachers are uncommon. However, if teachers have a solid background, they will teach the subject matter more effectively; hence, the need for this study.

Objectives

The study aimed to determine the extent to which manipulatives could enhance pre-service students' conceptual understanding of fractions.

Hypothesis

Based on the purpose, it was hypothesised that;

H0: There is no significant difference between pre-service teachers' performance before and after the intervention.

METHODOLOGY

Before conducting the research, permission in writing was obtained from the principal. Participants were briefed on the issues surrounding voluntary participation. Participants were again guaranteed confidentiality and anonymity. The research employed a quasi-experimental design. A quasi-experimental design assigns study participants to conditions in a non-random manner (Pandey & Pandey, 2021). Thus, neither randomisation nor a control group existed, but there was treatment (intervention). Due to school configurations, the researchers could only utilise intact classes (Kothari, 2017). The one-group Pre-test and Post-test post-test design was used to collect data for this study. According to studies, pre-and post-tests have been the primary instruments for data collection in numerous education-related studies (Gumilar et al., 2020; Saranya et al., 2021). Each participant is evaluated first under the control condition and then under the treatment condition. It has been proven effective because if the average score on the post-test post-test is higher than the average score on the pre-test, it is reasonable to conclude that the improvement is due to the intervention.

The targeted population was Akrokerri College of Education students. The college offers three bachelor's degree programmes in Early Grade Education, Upper Primary Education, and Junior High Education. The duration of each programme is four years; however, students spend the first three years on campus and the fourth year in field practice, where experienced teachers mentor them. Pre-service teachers are introduced to fractional mathematics in their first year of preparation. The second year focuses on teaching methods, while the third year is devoted to on-campus and off-campus practical sessions. In this regard, the researchers utilised the second-year pre-service Early Grade teachers (Crossman, 2018). The Early Grade was chosen because it will be responsible for the Lower Pupils. A stronger mathematics foundation at this level is essential to prepare young students for future mathematics. The total number of Early grade students was one hundred fifty (150), serving as the study's sample size.

To ensure validity, all test questions were adapted from previous WAEC questions, TIMSS questions, and other standardised exams (Pandey & Pandey, 2021). In addition, two senior mathematics tutors were hired to review the questions. After administering a pre-test to determine the level of difficulty pre-service teachers had with fractions, the intervention was implemented within three weeks using a variety of manipulatives to ensure the practicality of the lessons. The post-test post-test was also administered immediately after the intervention to determine whether or not the intervention was effective (treatment). During the analysis of the collected data, each student's score on both tests was entered into the SPSS version 22.0 data view. The data entered into the software were converted into frequency counts, percentages, and bar charts, which were then used to answer the study's research questions.

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RESULTS

Table 4.1: Frequency table showing the performance of students in the pre-test.

Pre-Test			
Marks	**Frequency**	**Percent (%)**	**Cumulative Percent**
1-5	26	17.3	17.3
6-10	69	46.0	63.3
11-15	42	28.0	91.3
16-20	7	4.7	96.0
21-25	4	2.7	98.7
26-30	2	1.3	100
Total	**150**	**100.0**	**100.0**

Source: Field Data, 2022

Table 4.1, shows the Pre-test performance of 150 students sampled for the study prior to the intervention. The highest mark, 26 – 30 was obtained by 2 (1.3%) respondents while the least mark 1 – 5 was obtained by 26 (17.3%) respondents. Majority of respondents (46.0%) obtained 6 – 10 marks followed by 42 (28.0%) who obtained 11 – 15 marks as shown in Figure 4.1

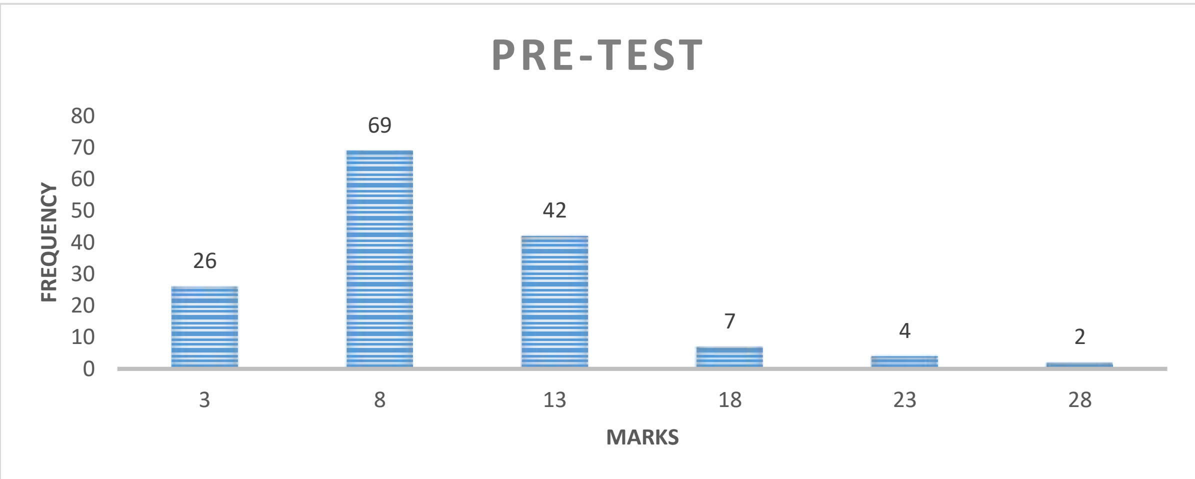

Figure 4.1 Bar chart showing Pre-test

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Table 4.2: Frequency table showing the performance of students in the post-test

Post-Test			
Marks	**Frequency**	**Percent (%)**	**Cumulative Percent**
1-5	2	1.3	1.3
6-10	5	3.3	4.6
11-15	19	12.7	17.3
16-20	33	22.0	39.3
21-25	40	26.7	66
26-30	51	34.0	100.0
Total	**150**	**100.0**	**100.0**

Source: Field Data, 2022

After the intervention, the post test scores showed that the highest score was $26 - 30$ obtained by 51 (34.0%) respondents. Although the least mark was $1 - 5$, only 2 (1.3%) had that scored as compared to the pre-test *(Table 4.1)*. About 92 (61.3%) of the respondents about $11 - 25$ marks in the post test (Figure 4.2) as compared to 53 (35.3%) students who obtained the same marks in the pre-test (Figure 4.1) showing an improvement after the intervention.

-test

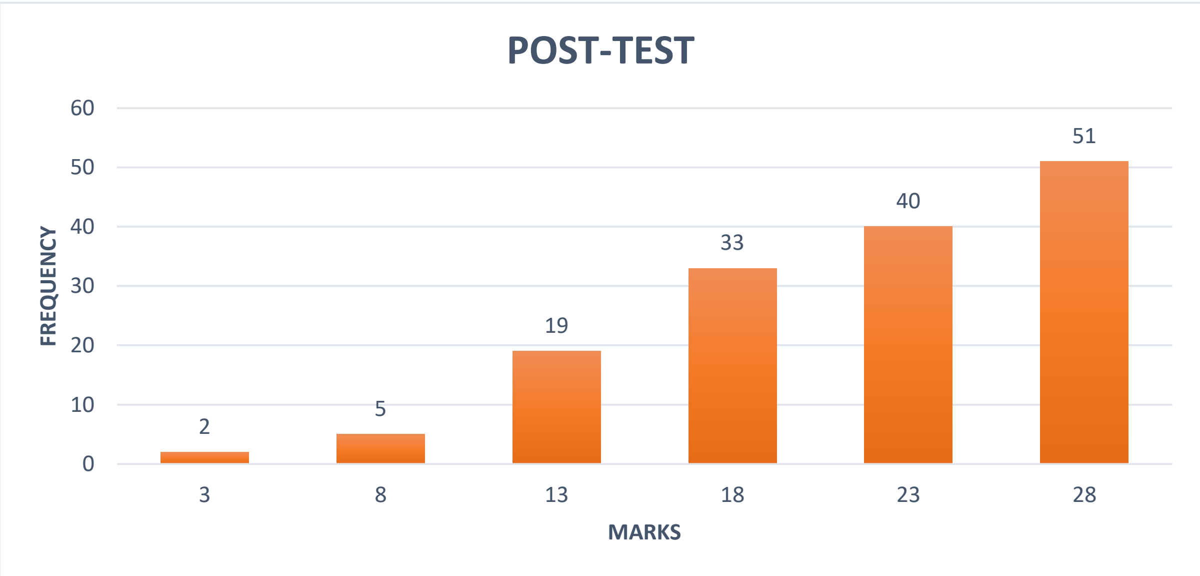

Figure 4.2 Bar chart of Post-Test

Table 4.3: Comparing the statistics of pre-test and post-test

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Paired Samples Statistics			
	Mean	**Std. Dev**	**Std Error Mean**
Pre-test	9.11	4.863	.397
Post-test	21.60	6.021	.492

Post test results showed a mean of 21.60 ($SD = 6.021, SEM = .492$), higher than the mean of the pre-test 9.11 ($SD = 4.863, SEM = .397$), indicating that the intervention that was implemented worked successfully (Table 4.3). This further shows that, majority of the students obtained higher marks in the post-test after the intervention as compared to the pre-test prior to the intervention. Figure 4.3 further shows that the pre-test is skewed to the left whiles the post-test shows a right skewness indicating a positive change in the students' performance over time as intervention was implemented.

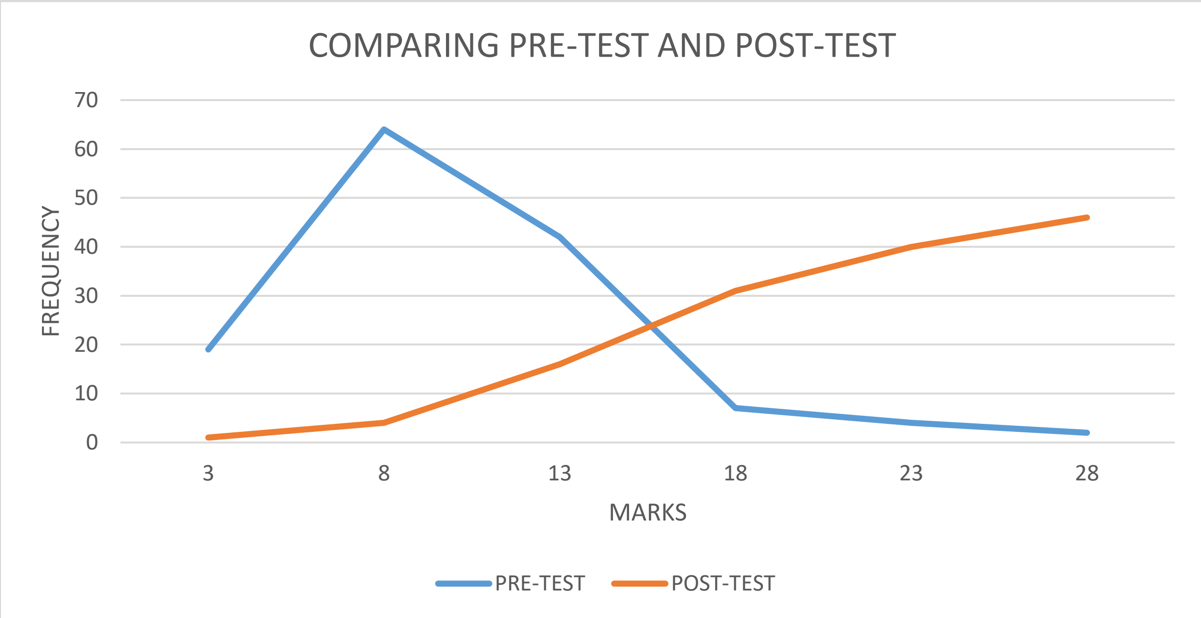

Figure 4.3 Comparing pre-test and post-test

To find out how significance the difference in the pre-test and post-test was, a "t" test was conducted to test the hypothesis

Ho**:** there will not be any significant difference in pre-service teachers' performance before and after the intervention

Table 4.4: Paired sample "t" test

	Paired Differences							
				95% Confidence Interval of the Difference				
	Mean	Std. Deviation	Std. Error Mean	Lower	Upper	**T**	**df**	**Sig. (2-tailed)**
Pre-test - Post-test	**-12.487**	**2.893**	**.236**	**-12.954**	**-12.020**	**-52.853**	**149**	**.000**

Since $t = -52.853$ and $(p = 0.000 < 0.05)$, we reject the null hypothesis (Ho) and conclude that there is significant difference in pre-service teachers' performance before and after the intervention. This indicates that the intervention of using physical manipulatives to build pre-service teachers' conceptual understanding of operation on fractions really worked.

DISCUSSION

The rejection of the null hypothesis a manifestation that the use of manipulatives is efficient in building conceptual understanding of learners; this time not only Young Pupils only but adults learners as well. The is in tandem with earlier researches like (Agyei et al., 2022; Satyam & Aithal, 2022) which observed that manipulatives use help learners. The results also confirm the assertion by (Cramer & Whitney, 2010; Lee et al., 2021). That the use of physical tools in teaching mathematics strengthen students' understanding of concepts including fractions

CONCLUSION

Base on the results of the study the researchers would like to conclude that the use of physical manipulatives is still efficacious for all pre tertiary levels.

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