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Hands-on Domain in Learning Mathematics: Impact on Students' Assessment Practices in Ghana

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Abstract

The study purposefully explored the effect of Hands-on activities on pre-service teachers' assessment in mathematics. The research employed a quasi-experimental design and utilized intact classes. One Hundred and Twenty (120) Level Three Hundred Pre-service teachers offering bachelor's degree programs in Junior High Education where purposively sampled. The one-group Pre-test and Post-test design was used to collect data for this study where each participant was evaluated first under the control condition and then under the treatment condition. The intervention was implemented within three weeks using manipulatives to ensure the practicality of the lessons. The post-test was also administered immediately after the intervention to determine its effectiveness. Results show a statistically significant ($t = -37.404, p = 0.000 < 0.05$). Hence the study concluded that the use of hands-on activities improves on students' performance in mathematics. It was recommended that, the teaching and learning of mathematics at the pre-tertiary level should incorporate hands-on activity method since it improves learners' assessment practices.

Keywords: Assessment, Hands-on, Manipulatives

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INTRODUCTION

There are three main domains of learning: cognitive, affective, and psychomotor domains (Menix, 1996). Teachers' knowledge about the three domains of learning can also influence their teaching practice in the classroom (Hatch et al., 2005). The emphasis of this study lies in exploring the psychomotor domain of learning, which centers on hands-on activities in the classroom.

Prior studies found that there is the need for a diverse range of engaging activities to enhance students' mathematical understanding (Kerrigan, 2018; Hritonenko et al., 2021). Hence, there is the need for teachers' abilities to relate the teaching and learning in the classroom to practical hands-on activities. Hands-on activities enhance conceptual understanding (Weaver, 1998) and make learning meaningful and enjoyable for most students (Rath & Brown, 1996). Ekwueme et al. (2015) revealed that hands-on activities impact students' academic performance in Basic Science and Mathematics. Baah-Duodu et al. (2020) noticed that mathematics should be taught utilizing hands-on and minds-on methods, which students may find enjoyable and may embrace as a lifestyle. For mathematics learning to be impactful on students' academic performance, it is necessary to connect mathematics teaching and learning to hands-on-activities in the classroom (Ekwueme et al., 2015). Recognizing the significance of hands-on-activities, teachers must allow learners to do a lot of hands-on-activities in the classroom during mathematics lesson.

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Students' learning and understanding, in most cases, pose challenges because of its abstract form. When solving problems, the type of activities children engages in using manipulatives affects what is learnt and how it can be applied (Bartolini & Martignone, 2020). Klu et al. (2023) found that the use of manipulatives is efficient in building conceptual understanding of learners; not only young pupils but adult learners as well. Similarly, earlier studies (Shin et al., 2017; Agyei et al., 2022) have observed that manipulatives help learners since the use of physical tools in teaching mathematics strengthen students' understanding of concepts. In conjunction with effective instruction and regular guided and unguided hands-on learning opportunities, learners gain a deeper and more expansive understanding of how to apply their knowledge to new circumstances (Bartolini & Martignone, 2020).

While previous studies and literature support the use of manipulatives in mathematics education, there is a lack of specific research on how hands-on activities specifically influence pre-service teachers' assessment practices in the Ghanaian context. Therefore, this study aims to address this gap by providing empirical evidence on the effectiveness of hands-on activities in improving students' performance and enhancing learners' assessment practices in mathematics.

The study is based on experiential learning. Experiential learning theory (ELT) which was originated by David Kolb in 1984 as a theory of learning is based on the concept of learning by doing. ELT mostly focuses on the idea that there are no other better ways to learn things than having experiences. Learning experiences tend to stick out in students' minds and help in the retention of the information and thereby foster recall of facts. Hands-on learning, often associated with ELT, engages students in sensory-stimulating activities (Vo, 2013). Through hands-on learning, students may apply information or gain new abilities. In instructional settings, students are required to conduct guided experiments with practical applications. This engages students in realistic real-world circumstances through presentations, conversations and practical activities, which make learning more engaging and enjoyable. Hands-on learning is advised for a variety of goals, including teaching individual's new (or old) abilities or assisting them in remembering and successfully utilizing knowledge. As implied by the term "hands-on learning," the student does specific tasks to better comprehend what is being taught.

Most empirical researchers provide evidence for the assumption that conducting hands-on activity strengthens student's abstraction of a concept which leads to positive motivational outcomes. Children require direct math experiences, engagement with other children and adults about their experiences, and time to reflect on those experiences (Ginsburg & Golbeck, 2004). Also, Seefeldt and Wasik (2006) noted that manipulatives may be utilized to teach several National Council of Teachers of Mathematics (NCTM) described topics, including problem solving, communication, reasoning, connections, and estimating. The authors emphasize that the use of manipulatives should "enhance children's understanding of numbers and operations, patterns, geometry, measurement, data analysis, problem-solving, logic, linkages, and representations."

A study by the National Centre for Education Statistics found that students who participated in a hands-on math program had higher math scores than those who did not. The study included 3rd, 4th,

and 5th grade students and found that hands-on learning had a particularly positive impact on students who had previously struggled with mathematics (Suh et al., 2017; Shi et al., 2023).

A study by Adu-Gyamfi et al. (2020) found that hands-on learning can improve mathematics performance among primary school students in Ghana. The study included 120 students from two primary schools and compared the effectiveness of hands-on activities with traditional instruction. The results showed that students who participated in hands-on activities had significantly higher mathematics scores than those who received traditional instruction. The authors concluded that hands-on learning can be an effective instructional strategy for improving mathematics education in Ghana. Owusu-Boampong and Larbi-Siaw (2019) also Beem (2020) found that hands-on learning can improve mathematics achievement among junior high school students in Ghana. The study included 180 students and compared the effectiveness of hands-on activities with traditional instruction. The results showed that students who participated in hands-on activities had significantly higher mathematics scores than those who received traditional instruction. The authors concluded that hands-on learning can be an effective instructional strategy for improving mathematics education in Ghana.

Furthermore, a study by Adjei and Agyei (2018) and Quansah (2021) found that hands-on learning can improve problem-solving skills among primary school students in Ghana. The study included 63 students and compared the effectiveness of hands-on activities with traditional instruction. There was a significant improvement in students who participated in hands-on activities as they had significantly higher problem-solving scores than those who received traditional instruction. Hence, hands-on learning can be an effective instructional strategy for developing problem-solving skills in mathematics education in Ghana.

The various studies in this field were conducted with classroom students. As a result, investigations involving Pre-service teachers are uncommon. However, teachers are the implementers of the curriculum so if teachers have a solid background, they will teach the subject matter more effectively; hence, the need for this study.

METHODS

The research employed the pragmatist paradigm because Pragmatists assisted the researcher in identifying the students' assessment on the Hands-on domain of Mathematics learning. Pragmatism holds that concepts are only pertinent to the extent that they support action and is more concerned with practical outcomes than abstract distinctions (Saunders et al., 2015). Although Pragmatists recognize that there are multiple ways of interpreting the world and conducting research, that no single point of view can ever provide a complete picture, and that there may be multiple realities (Saunders et al., 2015), this does not mean that they always use multiple methods; rather, they use the method or methods that enable credible, well-founded, reliable, and relevant data to be collected in order to advance the research.

The permission of the Akrokerri College of Education's principal and head of the mathematics department was obtained in advance and in writing. On an equal basis, participants were informed of the issues surrounding voluntary participation. Participants were again assured of their privacy and anonymity. The research design was quasi-experimental. A quasi-experimental design does not randomly assign participants to conditions (Pandey & Pandey, 2021; Klu et al., 2023). Consequently, neither randomization nor a control group existed, but treatment (intervention) did. Due to school configurations, researchers could only use whole classes (Klu et al., 2023).

This study used a one-group Pre-test and Post-test design to acquire data. In numerous education-related studies, pre- and post-tests have been the primary instruments for data collection, according to multiple studies (Gumilar et al., 2020; Klu et al., 2023). Each participant was evaluated in both the control and treatment conditions. If the average score on the 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, according to Klu et al. (2023).

Students from Akrokerri College of Education in the Ashanti Region of Ghana, specifically Adansi North, were the target audience. Priorities in the bachelor's degree programs for Early Grade Education, Upper Primary Education, and Junior High Education are Mathematics and Science Education. Each program is four years in length; however, students spend the first three years on campus and the fourth year in field practice, where they are mentored by seasoned instructors. The researcher employed a technique of purposive sampling in which only third-year students were included in the study because only third-year college students participate in hands-on activities. All 120 Level 300 Students offering bachelor's degree programs in Junior High Education were sampled on purpose. The Junior High level was selected because it will be accountable for Junior High Pupils who will be preparing for senior secondary education and will be required to pass the Basic Education Certificate Examination (BECE) in Mathematics. Young pupils must have a stronger mathematical foundation at this level to be prepared for future mathematics.

To assure veracity, all test questions on shape and space (Plane Geometry) were adapted from previous WAEC, TIMSS, and other standardized exams (Pandey & Pandey, 2021). In addition, two senior Mathematics Department instructors were assigned with reviewing the queries. After administering a pre-test to determine the level of difficulty pre-service teachers had in identifying the number of faces, vertices, perimeter, and area of plane shapes, the intervention was implemented using a variety of manipulatives to ensure the practicality of the lessons within three weeks. The post-test was also administered immediately after the intervention to determine the effectiveness (treatment) of the intervention.

The pre-service instructors' scores on both examinations were entered into the Statistical Package for the Social Sciences (SPSS, Version 22.0) for analysis. The software was used to convert the entered data into frequency counts, percentages, and bar charts, which were then used to answer the study's

research query. The hypothesis of the study was tested using a paired sample t-test to compare the methods of using hands-on activities and the traditional method.

RESULTS AND DISCUSSION

Table 1 and Figure 1 show the results of the pre-test scores of students prior to the intervention. Ten questions on Shape and Space (Plane Geometry) were given to pre-service teachers and were scored out of 30. The questions were on n Faces, Vertices, Sides, Perimeter and Area of Plane Shapes.

Table 1. Distribution of pre-test scores

Marks	Frequency (n=120)	Percent (%)	Cumulative Percent (%)
1-5	1	0.8	0.8
6-10	39	32.5	33.3
11-15	71	59.2	92.5
16-20	5	4.2	96.7
21-25	4	3.3	100.0

Out of the 120 pre-service teachers, 0.8% (n=1) had a score of 1-5, 32.5% (n=39) scored 6-10 marks whereas 59.2% (n=71) representing the majority scored 11-15 marks. Only 4.2% (n=5) and 3.3% n=4) score 16-20 and 21-25 marks respectively. Thus, 92.5% (n=111) of the students scored half or less of the total marks of 30 in the pre-test as shown by Figure 1.

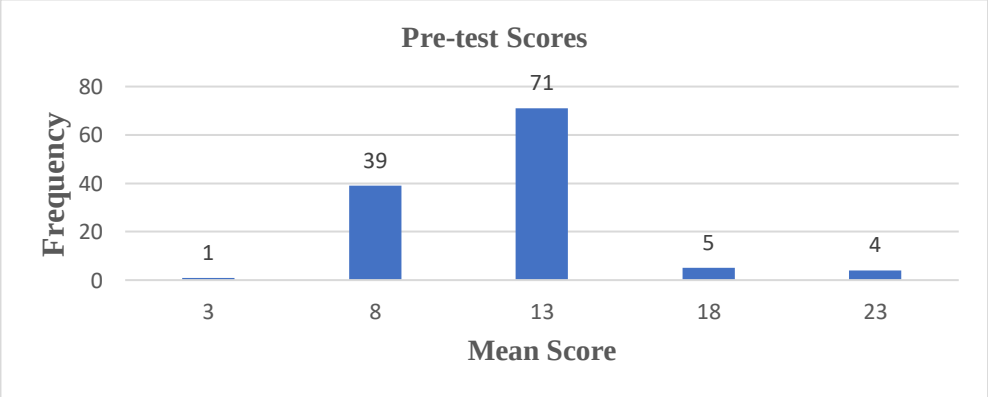

Figure 1. Bar chart showing the mean score of pre-test

From Figure 1, 7.5% (n=9) pre-service teachers scored above half. After the intervention of using hands-on activities (manipulatives) to teach the topic, a post-test was conducted to assess the impact on students' performance.

Table 2. Distribution of post-test scores

Marks	Frequency (n=120)	Percent (%)	Cumulative Percent (%)
6-10	6	5.0	5.0
11-15	8	6.7	11.7
16-20	16	13.3	25.0
21-25	27	22.5	47.5
26-30	63	52.5	100.0

From Table 2, majority of the pre-service teachers (88.3%, n=106) scored more than half in the post test whiles only 11.7% (n=14) scored half or less. The graphical representation of the post-test scores is shown by Figure 2.

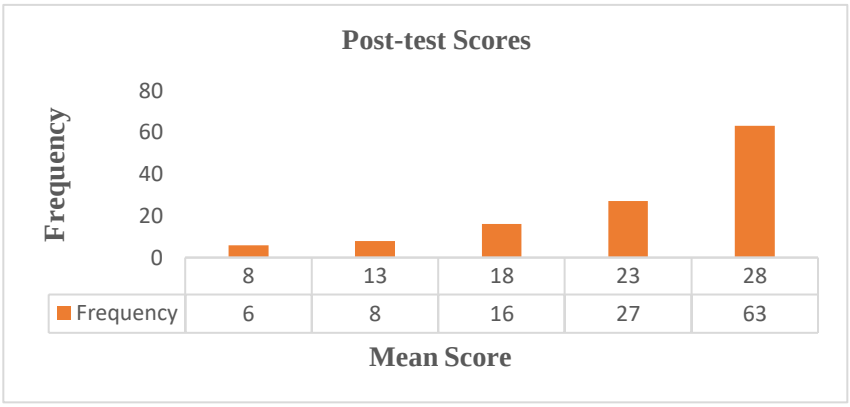

Figure 2. Bar chart showing the mean score of post-test

Comparing Pre-test scores to Post-test scores, Figure 2 shows higher scores over Figure 1 indicating that the intervention of using manipulatives worked. Figure 2 shows a least mark of 8 and highest mark of 28 whiles Figure 1 shows a least mark of 3 and a highest mark of 23. A paired sample test (Table 3) was conducted to ascertain the statistics of the pre-test and post-test to verify the impact of using hands-on activities in the teaching and learning of mathematics over the traditional method on students' assessment.

Table 3. Comparing statistics of pre-test and post-test

Paired Samples Statistics				
	Mean	N	Std. Deviation	Std. Error Mean
Pre-test Scores	11.7583	120	3.56452	.32539
Post-test Scores	24.3667	120	5.84812	.53386

The mean of the post-test was 24.37 ($SD = 5.848, SEM = 0.534$) higher than the mean of pre-test (Mean=11.76, SD=3.565, SEM=0.325). This indicates that participants had a higher assessment in the post-test resulting from the intervention of using hands-on activities in teaching Shape and Space (Plane Geometry).

To test whether there was a significant effect of hands-on activities on students' performance in mathematics; a paired samples test (t-test) at 95% Confidence interval was conducted on the pre-test and post-test results as shown by Table 4. However, prior to that, the data underwent testing to determine if it followed a normal distribution.

Table 4. Paired sample test (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	-1.26083E1	3.69259	.33709	-13.27580	-11.94087	-37.404	119	.000

From Table 4, t=-37.404 (p=0.000<0.05) which shows a statistically significant difference; hence we conclude that there is a significant effect of hands-on activities on students' conceptual understanding in mathematics. This implies that the use of hands-on activities in the teaching and learning of mathematics, positively impacts on students' understanding.

The study found a statistically significant difference in students' conceptual understanding of mathematics when hands-on activities were incorporated into the teaching and learning process. This supports the existing literature that emphasizes the positive impact of hands-on activities on students' academic achievement in mathematics (Ekwueme et al., 2015; Johnson et al., 1997; Hussain & Akhtar, 2013). The use of manipulatives and hands-on activities has been shown to enhance learners' understanding of various mathematical concepts, including numbers and operations, patterns, geometry, measurement, data analysis, problem-solving, logic, linkages, and representations mathematics (Seefeldt & Wasik, 2006). Additionally, the study aligns with the theoretical framework of experiential learning, which suggests that learning by doing leads to better retention of information and fosters recall of facts.

Furthermore, the findings of the study support the need for teachers to incorporate hands-on activities in the teaching and learning of mathematics, as it has been shown to improve learners' assessment practices and conceptual understanding. This is in line with previous research that has highlighted the importance of hands-on activities in enhancing students' academic performance in mathematics (Ekwueme et al., 2015; Mostofo & Zambo, 2015). The study's use of the pragmatist paradigm also aligns with the emphasis on practical outcomes and the collection of relevant data to advance research in the field of mathematics education.

Overall, the study's findings contribute to the existing body of literature by providing empirical evidence of the positive impact of hands-on activities on students' assessment practices and conceptual

understanding in mathematics. It underscores the importance of incorporating hands-on activities in mathematics education to enhance students' learning experiences and academic achievement.

CONCLUSION

This study provides valuable insights into the potential impact of hands-on activities on pre-service teachers' assessment practices and students' conceptual understanding in mathematics. By conducting pre-test and post-test assessments on pre-service teachers' understanding of Shape and Space (Plane Geometry) using hands-on activities, the study demonstrated a significant improvement in students' performance in mathematics. This finding underscores the potential of incorporating manipulatives and hands-on activities in mathematics education to enhance learners' assessment practices and conceptual understanding.

By highlighting the significant impact of hands-on activities on students' academic achievement and assessment practices in mathematics, this study underscores the importance of integrating practical, experiential learning into the teaching and learning process. This aligns with the theoretical framework of experiential learning, which emphasizes the value of learning by doing and its positive effects on knowledge retention and transfer.

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