DOI: https://doi.org/10.67203/jossme.2026.1l986htd

Journal of Studies in Science and Mathematics Education

ISSN: 2630-662x

Published: 08.11.2026

Volume (issue): 6(2)

Page: 235 – 243

Origami-Based Instruction and its Effect on Upper Basic Students' Achievement in Mensuration in Toto, Nasarawa State, Nigeria

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Abstract

The study investigated the effect of origami -based instruction on the mensuration achievement of upper basic students in Toto Local Government Area, Nasarawa state, Nigeria. A quasi - experimental design involving non-equivalent, non-randomised pretest and posttest control groups guided the study. Drawing from a population of 6,435 students (3,484 male and 2,951 female), a sample of 96 students (56 male and 40 female) was drawn through a combination of simple random and stratified random sampling techniques. Two research questions were posed and two corresponding null hypotheses were tested. Data were gathered with a single instrument, the Mensuration Achievement Test (MAT), which had been validated by three experts and whose internal consistency, established through the Kudet-Richardson Formula 21 (K-R21), yielded a reliability coefficient of 0.86. Mean and standard deviation were applied in answering the research questions, while Analysis of Covariance (ANCOVA) was used to test the hypotheses at 0.05 level of significance. Results showed that students exposed to origami -based instruction recorded markedly higher achievement in mensuration than their counterparts taught conventionally, and that the strategy benefited male and female students comparably, with no statistically significant gender desparity in outcomes. Based on the findings, it was recommended that mathematics teachers be encouraged to integrate origami -based activities into mensuration instructions, that students be guided to collaborate in mixed gender groups to narrow the gender gap and build a culture of cooperative problems-solving and that classroom practice generally shift towards learner-centered, hands -on engagement consistent with curriculum expectations for nurturing creative mathematical thinking.

Keywords: Origami-based instruction, teaching strategy, achievement, mensuration

1 Introduction

Mathematics is widely understood as the disciplined study of quantity, number, shape, pattern, and the relationships that bind them, drawing on computation, logical reasoning, and proof to resolve both abstract and applied problems (Philip, Eriona, & Narasimha, 2025). Its relevance cuts across fields as varied as information technology, engineering, medicine, and economics, where it supplies the analytical tools needed for sound decision-making and for detecting regularities in nature and in society (Munna, 2021). The discipline's significance has only grown with its deepening entanglement with big-data analytics, artificial intelligence, and digital technology more broadly (Joycelyn, 2025). Within Nigeria's education system, mathematics occupies a compulsory place at both the basic and secondary levels (Federal Republic of Nigeria, 2014). Yet one of the most persistent difficulties facing the subject in schools is less about exposure to content than about how durably students grasp and later retrieve mathematical ideas. Genuine learning calls for active, constructive engagement with mathematical concepts; students cannot simply be cast as passive recipients of knowledge transmitted by a teacher, but must be drawn into the process as contributors in their own right.

Mathematics education, in turn, denotes the body of methods and approaches through which mathematical concepts and operational skills are imparted to learners. It spans curriculum design, pedagogy, assessment, and research, all oriented toward deepening students' understanding and application of mathematical ideas. Godwin (2020) frames mathematics education as the bridge connecting abstract theory to practical use, equipping students with competencies relevant both inside the classroom and beyond it in the workplace. Because of this bridging function, mathematics education is inseparable from skills development, personal growth, and the broader project of workforce readiness and national economic advancement. In Nigeria generally, and in states such as Nasarawa specifically, the quality of mathematics instruction bears directly on whether the workforce of tomorrow can sustain industrial and technological progress.

Mensuration, a core branch of geometry, concerns itself with the measurement of geometric figures and associated parameters such as length, surface area, lateral surface area, and volume. Its applications extend from the everyday

household setting to industrial practice, and the expanding body of knowledge in this area carries tangible social and economic consequences. At the upper basic level, exposure to mensuration is expected to cultivate the foundational skills, knowledge, and problem-solving competence students need to navigate their physical environment (Ohodo, 2019); these competencies, in turn, sharpen the critical thinking required for everyday decision-making. Despite this promise, the manner in which mensuration is commonly taught has drawn criticism for being uninspired, repetitive, and at times outright dull (Akani, 2022). Many Nigerian secondary school students consequently regard mensuration as an abstract and troublesome topic, a perception rooted in difficulties with comprehension, retention, abstract formulation, dense terminology, the sheer multiplicity of formulae, and variation among learners (Airissa, 2021). The resulting disinterest in mensuration lessons, left unaddressed at the upper basic stage, threatens to undermine any later effort to raise achievement in the subject.

Achievement, for its part, denotes the successful completion of an academic task and is typically gauged to establish where a learner stands at a particular point in time (Akani, 2022). It functions as a check on acquired knowledge, enabling both teacher and learner to evaluate and project the extent of learning attained; it also signals the level of interest and skill present, and serves more broadly as a barometer of how effective and efficient a given mode of instruction has been (Kabutu, Oloyede, & Bandele, 2019). Table 1 below documents students' performance in mathematics in the Basic Education Certificate Examination (BECE) across Nasarawa State between 2021 and 2025.

Table **1**

Statistics of Students' Mathematics Achievement by Grade in the BECE (2021–2025), Nasarawa State

Year	Candidates Registered	% Grades A1–C6	% Grades D7–E8	% Grades F9
2021	13,780	31.52	32.04	36.44
2022	14,158	33.73	28.09	38.18
2023	14,825	35.68	31.54	32.78
2024	15,237	38.24	33.37	28.39
2025	17,158	26.94	37.45	35.61

Source: Department of Statistics, Ministry of Education, Nasarawa State (2025).

The figures in Table 1 indicate that the proportion of candidates obtaining credit passes (A1–C6) in mathematics has hovered persistently below 50 percent across the eight-year period under review, fluctuating without any sustained upward trend. Grades D7 and E8, while nominally passes, fall short of the threshold required for entry into science-based subjects at the senior secondary level. According to successive chief examiners' reports for 2021–2025, this underachievement traces largely to weak grasp of foundational principles, particularly geometry and mensuration. Additional contributing factors include school location, learners' cognitive readiness, socio-economic disadvantage, administrative bottlenecks, the use of inappropriate instructional strategies, and teacher-related weaknesses such as poor command of subject matter that leads to the skipping of topics. Efforts to raise the quality of mensuration instruction and overall mathematics achievement have not been absent, even if their impact remains limited. Several scholars, including James and Taiwo (2018), Offorma (2019), and Godwin (2020), trace the problem chiefly to teaching methodology, while others point to systemic or governmental shortcomings. Peters and De Smedt (2018) similarly observe that secondary mathematics teachers rarely make use of teaching aids, often relying instead on the lecture method, in which the teacher dominates discourse and students are reduced to passive listeners.

Teaching, understood as a deliberate cognitive activity undertaken by the instructor to realise specific learning goals, exerts considerable influence on achievement because learners process new information by relating it to what they already know. Properly conceived, teaching should produce observable, desirable change in learner behaviour, which makes the classroom learning environment central to how well a concept is internalised. Genuine learning surfaces when insight is gained and when interaction, whether between teacher and learner or among learners themselves, has actually taken place (Azige, 2019). Some teachers continue to operate as though knowledge can simply be handed over to students, yet learning is better understood as something achieved through doing, reinforced by innovative instructional approaches. Abdulhamid, Abubakar, and Tela (2018) argue that effective mathematics teaching demands methods that actively engage learners, and that without such engagement, students remain largely uninvolved in classroom activity. Amadioha (2019) similarly notes that students learn most effectively through active participation, a pedagogical orientation best realised through action-based communication in the classroom. Origami, the centuries-old Japanese art of paper folding, has found a place in contemporary classrooms as a tool for reinforcing mathematical problem-solving. Within instruction, it refers to a lesson

format in which the teacher guides students to discover or deduce mensuration properties and theorems from the shapes that emerge as paper is folded (Boakes, 2009). Beyond its conceptual value, origami builds fine motor skill: folding and shaping paper into a precise form demands coordinated, controlled finger movement, and repeated practice strengthens students' dexterity, their sensitivity to small movements, and the coordination between hand and eye (Anisa, 2021; Harsismanto, 2021). Woven into a mathematics lesson, origami can make the subject more approachable and enjoyable across a range of learning styles, while also nurturing concentration and patience, since producing a clean fold demands sustained focus and the discipline to follow a sequence of steps carefully (Cllaudia, 2018).

Origami also carries notable benefits for creativity (Wati, 2019). Shaping paper into a defined form pushes students to think beyond habitual patterns and to improvise solutions as they work toward a particular shape, a process that sharpens creative thinking, defined here as the capacity to find solutions that lie outside conventional reasoning. The activity equally cultivates imagination and inventiveness, since rendering complex or visually interesting forms requires students to picture, in advance, how a sheet of paper can be folded to yield the result they want (Wawointana, 2022). Taken together, origami strengthens creative capacity, trains creative thinking, develops imagination, and sharpens problem-solving (Husna, 2019). The repeated folding and unfolding of paper also nurtures an intuitive sense of symmetry, a quality central to both geometry and visual art, and helps students visualise geometric concepts in concrete terms; shaping paper into geometric forms, in particular, deepens their grasp of how shapes relate to one another and helps them recognise basic properties such as angle, side length, and symmetry (Bornasal, 2021). On the whole, then, origami offers a tangible route to enriching students' creativity within mathematics education.

Research evidence has increasingly demonstrated the potential of activity-based and manipulative instructional strategies, particularly origami-based instruction, in improving students' understanding and achievement in mathematics. Specifically, Unodiaku (2022), in a study conducted among senior secondary school students in Enugu State, Nigeria, found that the Origami-Based Instructional Model Approach (OBIMA) was effective in improving students' academic performance and interest in mensuration. Similarly, Unodiaku (2021) established that students taught mensuration theorems through an origami-based instructional model performed significantly better than those taught using conventional methods. The findings suggest that paper-folding activities can provide students with practical opportunities to explore geometrical relationships, understand mathematical principles and develop proofs of mensuration theorems. In addition, Kandil and Işıksal-Bostan (2019) reported that inquiry-based instruction enriched with origami activities significantly improved students' achievement in reflection symmetry and their self-efficacy in geometry. Boakes (2009) also examined the use of origami in mathematics instruction and highlighted its potential for developing students' spatial visualization and understanding of geometrical concepts.

With regard to gender differences, the findings of previous studies remain inconsistent. While Unodiaku (2021, 2022) reported no significant gender difference in students' mathematics achievement following origami-based instruction, Kebin (2024) found that male students performed better than female students in retaining geometrical concepts taught through origami. Similarly, Boakes (2009) reported a gender-related interaction in one measure of spatial visualization, although no significant difference was established in students' overall geometry knowledge. These contrasting findings suggest that gender may not have a consistent influence on students' achievement when participatory instructional strategies are employed. Consequently, further investigation is necessary to establish the effectiveness of origami-based instructional strategies in teaching mensuration and to determine whether significant gender differences exist in students' academic achievement and interest in the subject. Given this inconclusive picture, the present study determines the effect of origami-based instruction on the mensuration achievement of upper basic 2 students in Toto Local Government Area, Nasarawa State, Nigeria.

The study is anchored on Lev Semyonovich Vygotsky's Social Development Theory (1978). Vygotsky (1896–1934), often regarded as the father of modern constructivism, profoundly shaped later constructivist thinkers such as John Dewey and Jean Piaget, who built upon his foundational ideas. Central to his theory is the claim that knowledge is co-constructed, meaning individuals learn through and from one another, a process that gives rise to what he termed the Zone of Proximal Development (ZPD). Learning, in this framing, sets in motion internal developmental processes that can only operate when a learner is interacting with others in their environment and cooperating with peers; once internalized, these processes become part of the learner's independent developmental achievement. This stands in contrast to the conventional model in which a teacher simply transmits information to students. Vygotsky's framework instead promotes learning contexts that position students as active participants. The findings of the present study are expected to be of value to mathematics teachers, education policymakers, curriculum planners and developers, researchers, teacher-training institutions, and students themselves.

1.1 Statement of the Problem

A troubling pattern currently confronts mathematics education at every level: learner achievement continues to decline. Much of this decline can be traced to the persistence of deductive, teacher-centred instruction. Where teachers rely on non-activity-oriented approaches, students are afforded little room to participate in classroom activity, which in turn makes it harder for them to achieve the intended learning outcomes. Compounding this is many teachers' limited capacity to improvise instructional materials when standard resources are unavailable, leaving lesson objectives only partially met. The continued reliance on older instructional resources, such as textbooks, charts, the chalkboard, and conventional laboratory or workshop facilities, delivered through a teacher-centred approach, is increasingly out of step with the demands of a digital, internet-driven age. The strategies most commonly used to teach mensuration have widened the gap between learners and the concepts they are expected to master. One plausible remedy lies in adopting origami-based instruction as a more participatory alternative. It is against this backdrop that the present study was undertaken, to determine the effect of origami-based instruction on the mensuration achievement of upper basic 2 students in Nasarawa State, Nigeria.

1.2 Objectives of the Study

The study sought to determine the:

1. effect of the origami-based teaching strategy on students' achievement in mensuration.
2. effect of the origami-based teaching strategy on the achievement of male and female students in mensuration.

1.3 Research Questions

The study was guided by the following research questions:

1. What are the mean achievement scores of students taught mensuration using the origami-based strategy compared with those taught using the conventional method?
2. What are the mean achievement scores of male and female students taught mensuration using the origami-based strategy?

1.4 Statement of Hypotheses

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

H_{01}: There is no statistically significant difference in the mean achievement scores of students taught mensuration using the origami-based strategy and those taught using the conventional method.

H_{02}: There is no statistically significant difference in the mean achievement scores of male and female students taught mensuration using the origami-based strategy.

2 Methodology

The study employed a quasi-experimental design with non-equivalent, non-randomized pre-test and post-test control groups. It drew on a population of 6,435 students (3,484 male and 2,951 female), from which a sample of 96 students (56 male and 40 female) was selected. Schools were chosen through simple random sampling: two upper basic 2 schools were first randomly drawn from the Toto Area Educational Quality Evaluation Office, after which an intact class was randomly selected within each school. One intact class in each school was then randomly assigned to the experimental group consisting 47 (29 male and 18 female) students and the other to the control group 49 (27 male and 22 female) students by balloting, with class size confirmed through students' physical attendance. To account for gender as a moderating variable, stratified random sampling was used to divide students into male and female strata, an approach that gives every member of the target population an equal chance of selection and so limits bias that might otherwise compromise validity and reliability. Two research questions were posed and two null hypotheses formulated. Data collection relied on a single instrument, the Mensuration Achievement Test (MAT), validated by three experts and found, via the Kuder-Richardson

Formula 21 (K-R21), to carry a reliability index of 0.86. Mean and standard deviation were used to answer the research questions, and Analysis of Covariance (ANCOVA) was applied to test the hypotheses at the 0.05 significance level.

3 Results

3.1 Research Question One

What are the mean achievement scores of students taught mensuration using the origami-based strategy compared with those taught using the conventional method?

Table **2**

Mean Achievement Scores and Standard Deviation of Students Taught Mensuration Using Origami-based Strategy and Conventional Method

Teaching Strategy	Type of Test	No. of Students	Mean Score	Std. Dev.
Origami-based	Pre-test	47	11.94	3.117
Origami-based	Post-test	47	23.74	2.400
Control	Pre-test	49	11.65	2.314
Control	Post-test	49	16.55	2.011

Table 2 shows that students taught mensuration using origami-based instruction recorded a pre-test mean of 11.94 (SD = 3.117) and a post-test mean of 23.74 (SD = 2.400), while those in the control group recorded a pre-test mean of 11.65 (SD = 2.314) and a post-test mean of 16.55 (SD = 2.011).

3.2 Null Hypothesis One

There is no statistically significant difference in the mean achievement scores of students taught mensuration using the origami-based strategy and those taught using the conventional method.

Table **3**

ANCOVA on Students' Achievement Scores by Teaching Strategy

Source	Type III SS	df	Mean Square	F	p-value	Partial η^2
Corrected Model	1242.941	2	621.470	126.318	<.001	.731
Intercept	1846.779	1	1846.779	375.371	<.001	.801
Pre-test	1.510	1	1.510	.307	.581	.003
Group	1233.540	1	1233.540	250.726	.000	.729
Error	457.549	93	4.920			
Total	40381.000	96				
Corrected Total	1700.490	95				

R^2 = .731 (Adjusted R^2 = .725)

As shown in Table 3, the obtained F-ratio of 250.726 carries an associated probability value of 0.000, which falls below the 0.05 alpha threshold ($F = 250.726$, $p = 0.000 < \alpha = 0.05$). This signals a statistically significant difference in mean achievement between students taught mensuration through origami-based instruction and those taught conventionally, favoring the origami-based group. The null hypothesis is accordingly rejected, indicating that the origami-based strategy exerted a significant effect on students' post-test achievement scores.

An R^2 value of 0.73 indicates that the Origami-Based teaching strategy accounted for 73% of the variance in students' achievement in mensuration. This suggests that the strategy is highly effective in improving students understanding and achievement in mensuration, while 27% of the variance are attributable to other factors not included in the study. Therefore, an R^2 of 0.73 is considered high, indicating that the Origami-Based teaching strategy is a strong predictor of students' achievement in mensuration.

3.3 Research Question Two

What are the mean achievement scores of male and female students taught mensuration using the origami-based strategy?

Table **4**

Mean Achievement Scores and Standard Deviation of Male and Female Students Taught Mensuration Using Origami-based Strategy

Gender	Type of Test	No. of Students	Mean Score	Std. Dev.
Male	Pre-test	29	11.97	3.765
Male	Post-test	29	23.34	2.303
Female	Pre-test	18	11.89	1.711
Female	Post-test	18	24.39	2.400

Table 4 shows that male students recorded a pre-test mean of 11.97 (SD = 3.765) and a post-test mean of 23.34 (SD = 2.303), while female students recorded a pre-test mean of 11.89 (SD = 1.711) and a post-test mean of 24.39 (SD = 2.400).

3.4 Null Hypothesis Two

There is no statistically significant difference in the mean achievement scores of male and female students taught mensuration using the origami-based strategy.

Table **5**

ANCOVA on Male and Female Students' Achievement Scores Taught Mensuration Using Origami-based

Source	Type III SS	df	Mean Square	F	p-value	Partial η^2
Corrected Model	21.026	2	10.513	1.896	.162	.079
Intercept	1443.124	1	1443.124	260.331	.000	.855
Pre-test	8.919	1	8.919	1.609	.211	.035
Gender	12.357	1	12.357	2.229	.143	.048
Error	243.911	44	5.543			
Total	26764.000	47				
Corrected Total	264.936	46				

R^2 = .079 (Adjusted R^2 = .038)

Table 5 returns an F-ratio of 2.229 with an associated probability value of 0.143, exceeding the 0.05 alpha threshold ($F = 2.229$, $p = 0.143 > \alpha = 0.05$). This indicates no statistically significant difference in achievement between male and female students taught mensuration via origami-based instruction. The null hypothesis is therefore retained, suggesting that gender did not meaningfully moderate the effect of origami-based instruction on post-test achievement.

An R^2 value of 0.079 indicates that gender accounted for only 7.9% of variance in students achievement in mensuration taught using the origami-based teaching strategy, while 92.1% of the variance was due to other factors. Therefore, gender had a minimal effect on students' achievement under the Origami-based instructional approach.

3.5 Summary of Findings

1. Exposure to the origami-based teaching strategy enhanced students' achievement in mensuration.
2. Male and female students exposed to the origami-based strategy achieved comparably in mensuration.

4 Discussion of Findings

The findings indicate that origami-based instruction enhanced students' understanding and achievement in mensuration, as students exposed to origami-based activities performed significantly better than their counterparts taught through conventional instructional methods. This finding is consistent with Unodiaku (2021), who reported that students taught

mensuration theorems using an origami-based instructional model achieved significantly higher scores than those taught conventionally. Similarly, Unodiaku (2022) found that origami-based instruction improved secondary school students' academic performance and interest in mensuration. These findings suggest that the practical manipulation of paper into different geometrical shapes enables students to visualize mathematical relationships, explore geometrical properties and develop a better understanding of mensuration concepts. The result also agrees with Kandil and Işıksal-Bostan (2019), who found that integrating origami activities into inquiry-based geometry instruction significantly improved students' achievement in geometry. Boakes (2009) equally highlighted the contribution of origami activities to students' spatial visualization and understanding of geometrical concepts. Collectively, these findings suggest that origami-based instruction provides opportunities for active participation, practical exploration and visualization, which can improve students' achievement in mensuration.

Furthermore, the study revealed that male and female students taught through origami-based instruction achieved at comparable levels in mensuration, indicating that the instructional strategy did not produce a significant gender-based difference in academic achievement. This finding agrees with Unodiaku (2021, 2022), whose studies on origami-based instruction in mensuration reported no significant gender difference in students' academic performance. However, the finding differs from Kebin (2024), who reported that male students performed better than female students in retaining geometrical concepts taught through origami activities. These differences suggest that gender does not consistently determine students' achievement in mathematics and that the influence of gender may vary according to the instructional approach, mathematical content, learning environment and outcome being measured. Therefore, the present finding provides further evidence that origami-based instruction can create learning opportunities in mensuration that enable both male and female students to achieve comparable academic outcomes.

The improved performance recorded by the treatment groups can plausibly be attributed to a more enabling learning environment, one in which students engaged in hands-on, exploratory thinking through origami folding and collaborated by sharing ideas, assisting one another, offering explanations, and encouraging continued effort. A further contributing factor may be that students in the treatment groups were simply more engaged, attentive, and interested in the task at hand, conditions that allowed slower learners to catch up with their faster peers. Mensuration achievement, it would seem, stands to improve considerably when students are given greater ownership of their own learning. Peer interaction, in this respect, offers fertile ground for cognitive development. As Vygotsky's (1978) social learning theory holds, knowledge emerges through social interaction, and learning flourishes when individuals of comparable skill are exposed to tasks that invite shared thinking and manipulation of ideas.

5 Recommendations

1. Mathematics teachers should be encouraged to develop and adopt the origami-based strategy in teaching mathematics.
2. Students should be encouraged to work together in heterogeneous, mixed-gender groups to help narrow the gender gap and build a culture of cooperative learning.
3. Pre-service teachers should receive training in how to design and implement origami-based lessons in mathematics.
4. State governments should organise periodic seminars and workshops to keep in-service teachers updated on current and innovative instructional strategies at both lower and upper levels of education.
5. Mathematics teachers should continually explore current and innovative methods of instruction that promise greater effectiveness in the classroom.

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