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# Improving students' achievement in fractions using inquiry-based instructional strategy enriched with origami activities

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## ABSTRACT

Teaching fractions in primary schools presents challenges that require innovative instructional strategies. Inquiry-based learning, when enhanced with origami activities, provides a hands-on approach to improving students' understanding of fractions. This study examines the effects of an inquiry-based instructional strategy enriched with origami activities on students' achievement in fractions and the moderating effect of gender in Oyo State, Nigeria. A quasi-experimental pretest-posttest control group design with a 2×2 factorial matrix was used. The sample comprised 55 male and 33 female students from two randomly selected public primary schools. Two intact classes were randomly assigned to the experimental and control groups. Data were collected using a students' achievement test in fractions, and teachers' instructional guides, and the data were analyzed using analysis of covariance and estimated marginal means. The findings reveal a significant main effect of the instructional strategy on students' achievement, while gender did not have a significant effect. This suggests that the strategy is effective for diverse student groups. The study concludes that integrating origami into Inquiry-Based Learning (IBL) enhances students' fraction learning outcomes. The implications include advocating for interactive, hands-on teaching approaches in mathematics education and encouraging curriculum planners and educators to adopt engaging methodologies that foster deeper conceptual understanding.

# *Meningkatkan prestasi siswa dalam pecahan menggunakan strategi pembelajaran berbasis inkuiri yang diperkaya dengan aktivitas origami*

***Kata Kunci:***

*strategi pembelajaran berbasis inkuiri, aktivitas origami, prestasi belajar pada pecahan*

## *ABSTRAK*

*Pembelajaran pecahan di sekolah dasar sering kali menghadapi tantangan yang memerlukan strategi instruksional inovatif. Pembelajaran berbasis inkuiri yang diperkaya dengan aktivitas origami menawarkan pendekatan langsung untuk meningkatkan pemahaman siswa. Penelitian ini mengkaji pengaruh strategi pembelajaran berbasis inkuiri yang diperkaya dengan aktivitas origami terhadap pencapaian siswa dalam pecahan serta melihat efek moderasi dari gender di Negara Bagian Oyo, Nigeria. Penelitian ini menggunakan desain quasi-eksperimen pretest-posttest dengan matriks faktorial 2×2. Sampel terdiri dari 55 siswa laki-laki dan 33 siswa perempuan dari dua sekolah dasar negeri yang dipilih secara acak. Dua kelas utuh secara acak ditempatkan dalam kelompok eksperimen dan kontrol. Data dikumpulkan melalui tes pencapaian siswa dalam pecahan dan panduan instruksional guru, kemudian dianalisis menggunakan*

*analisis kovarians dan estimasi mean marginal. Hasil penelitian menunjukkan bahwa strategi instruksional memiliki pengaruh signifikan terhadap pencapaian siswa, sedangkan faktor gender tidak memiliki pengaruh yang signifikan. Ini menunjukkan bahwa strategi tersebut efektif diterapkan pada berbagai kelompok siswa. Penelitian ini menyimpulkan bahwa integrasi origami dalam pembelajaran berbasis inkuiri meningkatkan hasil belajar pecahan. Implikasi dari penelitian ini menyoroti pentingnya pendekatan pembelajaran interaktif dan berbasis pengalaman dalam pendidikan matematika, serta mendorong pendidik dan perencana kurikulum untuk mengadopsi metode yang lebih menarik guna meningkatkan pemahaman konsep siswa.*



**Contribution to the literature**

This research contributes to:

- Examining the use of IBL enhanced with origami activities to improve fraction achievement among primary school students.
- Applying origami specifically to fractions within an inquiry-based framework, unlike previous research focused on origami in geometry and spatial skills.
- Investigating gender effects, providing insights into equitable learning outcomes. These findings support origami's potential to make fraction learning more engaging and effective.

## 1. INTRODUCTION

Mathematics, as the foundation of all knowledge, plays a crucial role in supporting human life across various disciplines. It is interconnected with every aspect of the universe, from the smallest particles to the largest structures [1], encompassing the study of structure, order, numbers, space, and quantities [2]. This discipline is built on practices such as counting, measuring, and describing shapes, which form the basis of mathematical relationships. Furthermore, mathematics is indispensable for the scientific, technological, and economic progress of any nation [3], [4]. It also has practical relevance in daily life, impacting personal planning and life experiences [3]. Emphasizing strong mathematical foundations in primary and secondary education equips students with skills that can benefit their lives and support broader societal and economic development [5]. This focus on foundational mathematics education ensures that students are well-prepared to contribute meaningfully to both their communities and the global economy.

The Nigerian education curriculum views primary education as compulsory for children aged 6-12 years, and the rest of the education system is structured around this foundation [6]. Teaching mathematics in primary schools is crucial because it lays the groundwork for more advanced studies and supports daily life across various professions. The goal is to equip students with basic numeracy skills, problem-solving abilities, estimation, and data interpretation, all of which are essential for both personal and academic success. Fractions, as a key component of numeracy in primary school mathematics, represent the relationship between two quantities. They provide information about parts, units, and the whole and can signify various concepts, such as a portion of a whole, a proportion, or a magnitude on a number line [7]. Fractions are vital for fields such as the physical, biological, and social sciences, as well as in many middle-income occupations that do not require advanced mathematics, including nursing,

carpentry, and auto mechanics [8], [9]. A weak foundation in fractions can prevent individuals from pursuing advanced mathematics and limit career opportunities later in life [10]. Learners' competence in numeracy and literacy in the early grades significantly influences their academic achievement in subsequent years and affects their ability to master other subjects [11]. A solid understanding of fractions is also essential for grasping concepts such as measurement, algebra, rational numbers, and time.

Despite their importance, fractions remain a challenging concept for both teachers and students in Nigerian primary schools. They are consistently identified as one of the three most difficult topics in the primary school mathematics curriculum [12], presenting persistent teaching and learning challenges. These difficulties stem from the complex concepts involved, which are hard to both teach and learn, and they often arise early in primary education [13]. Struggles with fractions persist throughout middle school, secondary school, and even tertiary education [14]. Historically, fractions have been particularly challenging to master [15]. Students often view fractions as parts of a set rather than parts of a whole [16], and this misconception can lead to difficulties in other areas of mathematics, such as algebra, measurement, ratio, and proportion [17]. Addressing these foundational challenges is essential for supporting a broader understanding of mathematics and ensuring success in later mathematical domains.

The low performance of students in fractions and mathematics, more broadly, has been attributed to various factors. These include a lack of interest in the subject [18], ineffective teaching strategies employed by educators [19], [20], and a weak foundational understanding developed in the early stages of education [21]. Additional challenges include students' reasoning and numerical abilities [22], the complexity of the content, and the instructional approaches used by teachers [23]. Poor teaching methods have been identified as a primary factor contributing to students' struggles with fractions [24], [25]. Despite this, many teachers continue to rely on traditional methods, focusing heavily on textbooks, charts, and diagrams to teach mathematics, including fractions. Several innovative methods have been proposed to improve students' performance in fractions, such as the measurement approach [26], e-learning strategies [27], and the use of tools like GeoGebra [28]. Exploring and adopting these new methods may provide teachers with effective alternatives to enhance students' understanding and performance in fractions.

IBL involves learning through questions and experimentation [29], and it fosters a "culture of inquiry," where "teachers become learners, learners teach themselves and peers, and everyone becomes a researcher" [30]. IBL is an active approach that allows students to experience the subject authentically and engage in high-level mathematical work [31]. Numerous efforts have been made to strengthen mathematics learning by adopting an inquiry-based teaching approach [32]. IBL emphasizes responsiveness, authenticity, and intellectual engagement, making it an effective approach for ensuring that students fully benefit from their shared learning environment [33]. This strategy actively engages students in the learning process, allowing them to explore content independently, thus providing more opportunities for deeper understanding and the development of critical thinking skills [34]. As a result, IBL not only enhances students' comprehension of mathematical concepts but also cultivates their problem-solving abilities and collaborative learning skills.

Several studies have shown that students taught through inquiry-based methods perform better than those taught using traditional methods [35], [36]. Inquiry-based mathematics instruction has been found to improve students' achievement in mathematics [37]. Additionally, IBL has been shown to support higher-level cognitive interaction

[38]-[40], longer-term knowledge retention [41], [42], and more efficient collaboration [43]. However, there are limited studies on the impact of IBL enriched with origami activities on students' achievement in fractions in Nigeria.

The role of origami in teaching and learning fractions is of significant importance. Origami, a Japanese term where "ori" means "to fold" and "gami" means "paper," refers to the art of paper folding. Origami serves as a bridge between nature and mathematics [44], [45]. It holds great mathematical potential, especially in education [46], particularly in geometry [47]. Origami activities in geometry lessons have been shown to improve high school students' achievement in geometry [48] and enhance their mathematical problem-solving abilities [49]. Origami-based mathematics instruction has also been found to significantly increase students' spatial ability scores [50]. In addition to geometry, origami can be applied to teaching fractions, algebra, spatial visualization, sequences, and trigonometry. However, studies exploring the use of origami activities to improve students' achievement in fractions in Nigeria are scarce.

Gender has been identified as a variable influencing instructional strategies, with many studies showing a significant achievement gap favoring male students in mathematics [51]-[55]. However, some argue that the perceived male superiority in mathematics is a result of societal views that consider mathematics a domain for males. Studies have also shown no significant relationship between gender and achievement in mathematics [56], [57]. This inconsistency in gender-related findings warrants further investigation. Therefore, this study examines the effect of inquiry-based instruction enriched with origami activities on students' achievement in fractions and the role of gender.

Students often struggle with fractions, and conventional teaching methods have proven ineffective in improving their performance. While various strategies like the Measurement Approach, GeoGebra, and E-learning have been explored, few studies integrate origami activities into an inquiry-based instructional strategy alongside gender analysis. This approach, which centers on students' questions and active engagement, promotes reasoning skills but is not widely practiced in mathematics teaching. This study aims to investigate the effectiveness of inquiry-based instruction enriched with origami activities on students' achievement in fractions and examine the moderating effect of gender.

Previous research has explored the use of origami in mathematics learning for various purposes, including exploring geometry and calculus concepts through origami boxes [45], using origami instructions to enhance geometry knowledge [46], improving mathematical problem-solving skills [49], teaching mathematics to deaf students [1], and developing spatial intelligence [2]. Despite these studies, research on integrating origami activities with instructional strategies, particularly inquiry-based learning, has not been conducted. This study addresses this gap by introducing an inquiry-based instructional strategy through origami activities, with the aim of improving student achievement.

## 2. METHOD

This study employed a pretest-posttest control group quasi-experimental design using a 2 × 2 factorial matrix. The research involved Basic Three students from two public schools in the Akinyele Local Government Area of Oyo State, Nigeria. The topic selected for the experiment was fractions, with subtopics including fractions of shapes, unit fractions, equivalent fractions, and ordering of fractions. These subtopics were part of the 9-year basic education curriculum for mathematics for primary levels 1-3 [58]. Convenience sampling was used to select two primary schools in the Akinyele Local

Government Area. Following ethical approval, the research was conducted. Two intact Basic Three classes, one from each school, participated in the study. Parental and student consent was obtained before the research commenced. The schools were selected based on the following criteria: (a) they must be public schools; (b) they must have experienced teachers with relevant qualifications; and (c) their mathematics teachers must be willing to participate in the experiment.

The instruments used for the study included: (a) Students' Achievement Test in Fraction (PATF); (b) Teachers' Instructional Guide on Inquiry-Based Instructional Strategy enriched with Origami Activities (TIGIISOA); (c) Teachers' Instructional Guide on Conventional Instructional Strategy (TIGCIS); and (d) Evaluation Sheet for Assessing Teachers' Performance during Training (ESATPT).

The PATF was adapted from the Mathematics Association of Nigeria's primary three textbooks to measure students' achievement in fractions. It consisted of two sections: Section A collected personal data about students, such as school name, class, sex, and age, while Section B contained 15 multiple-choice items with four options. Experts in test construction validated the PATF. The reliability of the instrument was determined by administering the Fraction Achievement Test to a sample of 40 students selected outside the target sample. The reliability coefficient was calculated using the Kuder-Richardson formula (K-R20), yielding a value of .72, which was deemed suitable for the study.

Students in the experimental group received fraction lessons using an inquiry-based instructional strategy enriched with origami activities, supported by materials such as origami papers, crayons, rulers, and pencils. The teachers' guide, validated by experts, incorporated inquiry-based instruction and origami activities with various student tasks. In contrast, the control group received conventional fraction lessons using a teacher-dominated guide, which was also validated for consistency. The ESATPT, developed to assess research assistants and evaluate teachers' use of the instructional guide, included two sections: Section A for personal data and Section B, a 5-point rating scale to assess different stages of the instructional strategy (ranging from very good to very poor).

Experts in test construction and mathematics education established the validity of the instruments. Three raters evaluated the instruments to assess the performance of teachers using the two strategies to teach fractions. The inter-rater reliability indices of the instruments were determined using the Scott's Pi (Scott $\pi$) method, which yielded values of .79 and .72 for the inquiry-based instructional strategy enriched with origami activities and the conventional instructional strategy, respectively. These reliability indices indicate substantial agreement among the raters.

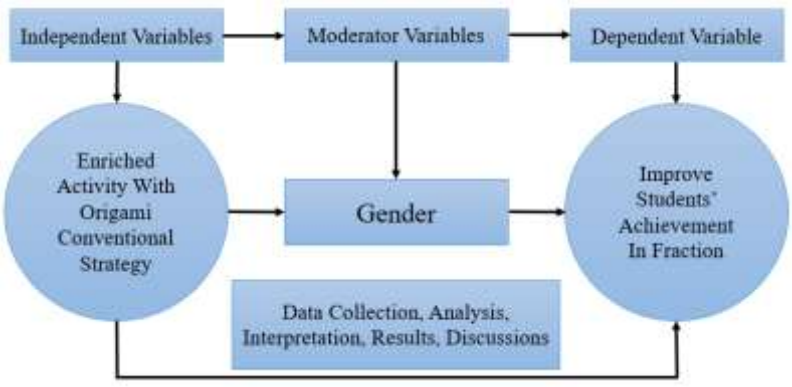


**Figure 1.** Study Flowchart

The regular mathematics teachers of the two intact classes were trained as research assistants for one week. Prior to the commencement of the treatment, all students completed the students' achievement test in fractions as a pretest. The treatment was applied over four weeks. The two intact basic three classes were randomly assigned to the treatment and control groups. The students were taught by their regular mathematics teachers, who had been trained for this purpose, under the supervision of the researcher. Each lesson lasted 45 minutes daily. The topic of the study was fractions, with subtopics including unit fractions, fractions of shapes, equivalent fractions, and ordering of fractions. After the completion of the treatment, all students completed the same Achievement Test in Fractions (PATF) as a post-test. The data collected were analyzed using Analysis of Covariance (ANCOVA) at the 0.05 level of significance.

## 3. RESULTS AND DISCUSSION

This section presents the results of data analysis on the impact of IBL strategies, enhanced with origami activities, on students' achievement in fractions. The discussion focuses on the main effects of the treatment and examines the role of other variables, such as gender, in influencing students' learning outcomes. To test the first hypothesis (Ho1), which states that there is no significant main effect of the treatment on students' achievement in fractions, an analysis of variance was conducted. The findings from this analysis, shown in Table 1, reveal a significant effect of the applied teaching strategy.

**Table 1.** Analysis of Covariance (ANCOVA) Showing the Effect of Treatment and Gender on Achievement in Fraction

| Source | TYPE III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared |
|---|---|---|---|---|---|---|
| Corrected Model | 85.280[a] | 4 | 21.320 | 6.010 | .000 | .225 |
| Intercept | 480.380 | 1 | 480.380 | 135.417 | .000 | .620 |
| Pretest | 0.523 | 1 | .523 | .147 | .702 | .002 |
| Treatment | 76.714 | 1 | 76.714 | 21.625 | .000* | .207 |
| Gender | 7.013 | 1 | 7.013 | 1.977 | .163 | .023 |
| Treatment x Gender | 5.037 | 1 | 5.037 | 1.420 | .237 | .017 |
| Error | 294.436 | 83 | 3.547 | | | |
| Total | 3755.000 | 88 | | | | |
| Corrected Total | 379.716 | 87 | | | | |

R Squared = .23 (Adjusted R Squared = 0.19) *denotes significant at .05 level of significance

Table 1 demonstrates a significant main effect of the treatment on students' achievement in fractions ($F(1,87) = 21.63$, partial $\eta^2 = .21$, $p < .05$). The effect size of 21% indicates a substantial improvement in students' achievement in fractions following the intervention. This suggests that null hypothesis 1 is rejected. In light of the observed main effect, the marginal means were used to determine the mean post-achievement scores of students in each group (experimental and control), as shown in Table 2.

**Table 2.** Estimated Marginal Means for Post-Achievement Scores by Treatment

| Treatment | Mean | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|
| | | | Lower Bound | Upper Bound |
| Experimental group | 7.17 | .29 | 6.60 | 7.74 |
| Control group | 5.22 | .31 | 4.61 | 5.83 |

Table 2 shows that the experimental group had a higher adjusted post-achievement mean score (7.17) compared to the control group (5.22). This difference favors inquiry-based instruction enriched with origami activities. This implies that students taught using

the inquiry-based instructional strategy, enriched with origami activities, achieved higher in fractions than those taught using the conventional instructional strategy.

Ho2: There is no significant main effect of gender on students' achievement in fractions. The results from Table 2 indicate that the main effect of gender on students' achievement in fractions was not significant ($F(1, 83) = 1.98$, $p > .05$) at the 0.05 level of significance. Therefore, the null hypothesis stating that there is no significant main effect of gender on students' achievement in fractions was not rejected. However, a slight difference in achievement based on gender is presented in Table 3.

**Table 3.** Estimated Marginal Means of Post-Achievement Scores by Gender

| Gender | Mean | Std. Error | 95% Confidence Interval | |
|---|---|---|---|---|
| | | | Lower Bound | Upper Bound |
| Males | 5.90 | .26 | 5.39 | 6.41 |
| Females | 6.49 | .33 | 5.83 | 7.14 |

Table 3 shows that females had a slightly higher adjusted post-achievement mean score (6.49) compared to males (5.90). The mean difference (.59) favored females, although the difference was not statistically significant. This suggests that gender (whether students are male or female) does not significantly affect students' achievement in fractions.

Ho3: There is no significant interaction effect of treatment and gender on students' achievement in fractions. The results in Table 1 revealed that the interaction effect of treatment and gender was not significant ($F(1,83) = 1.42$, $p > .05$). Therefore, the null hypothesis, which posits that there is no significant interaction effect of treatment and gender on students' achievement in fractions, is retained. This indicates that treatment and gender do not interact to influence students' achievement in fractions.

Teaching mathematics in primary schools is essential as it lays the foundation for advanced studies and supports various professions in daily life. The goal is to equip students with basic numeracy skills, problem-solving abilities, estimation, and data interpretation, which are critical for personal and academic success. This finding aligns with Ferguson [37], who demonstrated that inquiry-based mathematics instruction enhances students' achievement. Students exposed to inquiry-based instruction scored significantly higher in mathematics than their counterparts taught with traditional methods [35], [36], [59], [60]. These results are consistent with studies showing that IBL supports higher-level cognitive interactions [39], longer-term knowledge retention [41], [42], and more efficient collaboration [43].

The study found no significant main effect of gender on students' achievement in fractions. This result is in line with the findings of Ajai and Imoko [61], who observed no significant differences in achievement and retention between male and female students in mathematics. Similarly, no significant differences were found in achievement and retention between male and female students taught using origami [62], [63]. These findings contradict studies reporting gender differences in mathematics learning, where males were found to be superior [53]-[55], [65], [66]. Moreover, the findings indicated that female students had a higher mean score than their male counterparts in their achievement in fractions, although the difference was not significant. This suggests that both inquiry-based strategies and origami are gender-friendly and effective for teaching fractions.

The study also showed no significant interaction effect between treatment and gender on students' achievement in fractions, indicating that the treatment was not biased toward either gender. This aligns with previous research that found no significant

interaction effect between group and gender in paper folding and surface development tests [46]. However, this finding contrasts with research demonstrating a significant moderating effect of gender on students' performance [37]. Boakes [46] also revealed a significant interaction effect between group and gender in a card rotation test.

While this study highlights the effectiveness of an inquiry-based instructional strategy enriched with origami activities in improving students' achievement in fractions and bridging the gender gap, there are some limitations. The research was conducted in only two public schools in Oyo State, focused solely on fractions, and lasted for just four weeks, which may limit the generalizability and long-term applicability of the findings. Additionally, the study did not explore the method's application to other mathematical topics or its mechanisms for achieving gender equality in depth. Moreover, the success of the method was heavily dependent on teacher training, underlining the need for broader institutional support, such as in-service training programs organized by educational authorities and professional organizations. Future studies should address these gaps by expanding the sample size, extending the duration of the study, and testing the approach across various contexts and topics.

## 4. CONCLUSION

Based on the study's findings, inquiry-based instruction enriched with origami activities significantly improved students' achievement in fractions compared to conventional methods. While gender had no significant effect on achievement, females showed slightly higher performance. Furthermore, gender did not moderate achievement. The study highlights several educational implications for students, teachers, and curriculum planners. Active student participation enhances achievement and makes lessons more engaging. Teachers are encouraged to adopt the inquiry method alongside origami activities, which actively involve students in exploring, discovering, drawing conclusions, reflecting, evaluating, and reporting their findings. This approach not only deepens students' understanding of fractions but also fosters higher-order thinking skills. Finally, curriculum planners are urged to design curricula that support conceptual change over time. The study advocates for active, hands-on approaches in mathematics education, providing valuable insights for teachers and curriculum planners.

## AUTHOR CONTRIBUTION STATEMENT

AT contributed to the study design, the development of the inquiry-based instructional strategy with origami activities, supervision of data collection, and manuscript drafting, including literature integration and findings. FAS contributed to the implementation of the instructional strategy, data collection, methodology refinement, result analysis, and manuscript review to enhance educational insights. Both authors approved the final version.

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