Journal on Mathematics Education
Volume 16, No. 3, 2025, pp. 1077-1092

Bridging learning gaps: Testing the efficacy of simulation-based instruction on the mastery of fractions

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Received: 13 July 2025 | Revised: 25 September 2025 | Accepted: 29 September 2025 | Published Online: 30 September 2025

Abstract

Persistent underachievement in mathematics, particularly in foundational concepts such as fractions, remains a critical challenge in many African educational systems, including Nigeria. Despite numerous interventions, existing instructional approaches often fail to adequately address pupils' conceptual understanding, highlighting the need for innovative pedagogical strategies. This study introduces simulation-based instruction as a novel approach to enhance pupils' comprehension of fractions at the primary school level. The research aimed to examine the effect of simulation-based instruction on pupils' achievement in fractions in Ogun State, Nigeria. A mixed-methods design was adopted, involving 102 pupils from two intact classes in schools administered by the State Universal Basic Education Board, Abeokuta South. Quantitative data were collected using a Fraction Achievement Test (reliability coefficient = 0.72), while qualitative insights were obtained from a Students' Perception Interview Guide on Simulation. Both experimental and control groups completed pretests and posttests, with analysis conducted using ANCOVA. Results indicated a statistically significant improvement in the experimental group (Mean = 16.1, SD = 3.69) compared to the control group (Mean = 10.6, SD = 2.50), $F(1, 99) = 50.70$, $p < .05$, with 51% of variance explained by the treatment effect. The findings demonstrate that simulation-based instruction substantially enhances pupils' achievement in fractions, suggesting its potential for broader implementation in mathematics education to bridge persistent learning gaps and promote equitable academic attainment.

Keywords: Fractions, Intervention, Learning Gaps, Mastery, Simulation-Based Instructions

How to Cite: Odekeye, O. T., & Jita, T. (2025). Bridging learning gaps: Testing the efficacy of simulation-based instruction on the mastery of fractions. *Journal on Mathematics Education, 16*(3), 1077–1092. https://doi.org/10.22342/jme.v16i3.pp1077-1092

Mathematics is a fundamental subject worldwide, playing a critical role in national development and in fostering individuals' problem-solving, logical reasoning, and analytical skills (Bright et al., 2024). In many African countries, including Nigeria, research indicates that persistent underachievement in mathematics remains a significant concern with global implications, as poor performance in mathematics often negatively affects performance in other science disciplines (Oladejo & Olateju, 2025). This underachievement is frequently attributed to inherent challenges in instructional methods, which can lead to low student motivation, passive learning behaviors, and repeated academic failures (Doabler et al., 2022; Rojo et al., 2023). Consequently, students' difficulties in higher grades often reflect insufficient conceptual understanding acquired in earlier grades.

A further challenge lies in the development of personalized learning pathways that accommodate individual students' needs, enabling them to progress at their own pace while communicating effectively with teachers regarding their strengths and areas for improvement (Christopoulos et al., 2020). Despite numerous interventions, the effectiveness of strategies implemented to teach mathematics at all levels remains questionable (Awofala & Lawani, 2020). Student performance is influenced by multiple interrelated factors, encompassing student characteristics, teacher practices, and school environments (Belbase, 2024). Among these, teaching methods are frequently cited as a major teacher-related determinant of students' mathematical achievement (Awado et al., 2024).

In recent years, a variety of innovative tools and digital platforms have emerged to support mathematics instruction, offering educators potential avenues for more effective pedagogy (Serin, 2023). However, improvements in instructional practices and learning outcomes have been limited (Hillmayr et al., 2020), largely because many teaching approaches continue to rely on rote memorization and procedural instruction, which are widely criticized for failing to promote meaningful conceptual understanding (Sujatha & Vinayakan, 2022). Modern mathematics instruction increasingly integrates technological tools to enhance teaching efficiency and learning effectiveness.

Methods that present mathematical concepts abstractly without sufficient scaffolding have long been recognized as suboptimal, particularly for younger learners who benefit from hands-on, visual, and interactive approaches (Calor et al., 2024). Given the growing importance of mathematics in problem-solving, digital literacy, and 21st-century skills, there is an urgent need for instructional innovations that render abstract concepts more accessible and engaging across all educational levels (Ndibalema, 2025; Zou et al., 2025). For primary school pupils, who are still developing the cognitive skills required for abstract reasoning, such innovations are not merely beneficial—they are essential.

Empirical evidence suggests that pupils are particularly motivated by video-based learning, which captures attention while promoting engagement and enjoyment (Förster et al., 2022). Beyond sustaining interest, instructional videos offer a powerful medium for achieving educational objectives (Valencia et al., 2023). Consistent with this, Bailey et al. (2022) and Galatsopoulou et al. (2022) report that students exhibit positive attitudes toward video-enhanced learning, as videos can be incorporated into diverse active learning environments to foster engagement, enhance motivation, and create supportive learning conditions. Collectively, these findings underscore the potential of video-based instructional strategies—such as simulation-based mathematics instruction—in simplifying abstract concepts and maintaining learner interest through visual and interactive elements.

Fractions are among the most challenging yet fundamental topics in primary mathematics, serving as the foundation for understanding more advanced concepts such as ratios, proportions, algebra, geometry, probability, and trigonometry (Namkung & Fuchs, 2019). Despite their importance, many learners struggle to grasp fractions due to their dual nature as both numbers and operations, as well as the abstract part-whole relationship they represent (Gesuelli & Jordan, 2024). A common learning gap arises when students compare fractions by examining only the absolute differences between numerators and denominators, rather than understanding the intrinsic value of the fractions themselves (González-Forte et al., 2023).

Misconceptions often occur when students interpret these differences as the number of parts needed to complete a whole. Learners frequently struggle to distinguish between whole numbers and fractions, leading to errors such as assuming $\frac{1}{4}$ is greater than $\frac{1}{2}$ based solely on the numerators, without considering the critical relationship between numerator and denominator (Ren & Gunderson, 2021). These challenges underscore the need for instructional strategies that promote conceptual understanding rather than rote memorization, as the examples and explanations provided by teachers significantly shape students' comprehension (González-Forte et al., 2023; Awaah et al., 2023). The effectiveness of such interventions, however, depends largely on the quality of implementation, the teacher's pedagogical knowledge, and learners' prior mathematical experiences.

Simulation-based instruction has emerged as an innovative pedagogical approach to address these challenges. Grounded in constructivist learning theories, simulations allow learners to actively construct knowledge through meaningful, context-based experiences (Piaget, 1970; Vygotsky, 1978). By situating abstract concepts in practical contexts, providing immediate feedback, and reducing extraneous cognitive load, simulations foster deeper engagement and facilitate learning retention (Louw, 2021). Empirical studies have demonstrated that simulation-based instruction enhances students' critical thinking, creativity, and long-term retention while promoting the effective application of knowledge in classroom settings (Smith & Johnson, 2020; Kibirige & Tsamago, 2019).

Simulation-based instruction provides a practical learning environment that closely replicates real-world experiences, mitigating constraints commonly encountered in traditional classrooms (Perkins et al., 2006). It has been identified as an effective method for developing complex skills, particularly when integrated thoughtfully with clear learning objectives, structured feedback, and opportunities for reflection (Chernikova et al., 2020; Gerace, 2020). Prior research demonstrates the successful use of simulation for teaching complex, abstract, and challenging topics, resulting in improved student performance and attitudes toward learning (Talan, 2021; Barker & Warner, 2023).

Although simulation-based instruction has been widely applied across various educational fields (Fischetti et al., 2021), its integration in early-stage mathematics remains limited (Levin & Flavian, 2022; Frei-Landau & Levin, 2022). This gap is particularly relevant in contexts with limited resources, inadequate instructional materials, and a predominance of teacher-centered approaches. Insights from the Nigerian context can contribute to the global discourse on technology-enhanced learning, instructional innovation, and equity in mathematics education. Consequently, investigating the efficacy of simulation-based instruction in improving primary school pupils' achievement in fractions carries significant implications for bridging learning gaps and enhancing engagement in mathematics.

This study sought to investigate the effectiveness of simulation-based instruction in enhancing primary school pupils' understanding and performance in fractions. Specifically, it aimed to determine whether the use of simulation-based teaching strategies could significantly improve students' academic achievement compared to conventional lecture-based instruction. Additionally, the study explored students' perceptions of simulation-based instruction, examining how learners experience and respond to this innovative approach in terms of engagement, motivation, and understanding of abstract fractional concepts. To guide the investigation, the study tested the null hypothesis that there would be no statistically significant difference in the achievement of students taught fractions using simulation-based instruction and those taught through the conventional lecture method, at a 0.05 level of significance. By addressing these questions, the study sought to provide empirical evidence on the pedagogical value of simulation-based learning and its potential to enhance conceptual understanding, instructional engagement, and overall performance in primary mathematics.

METHODS

Research Design

The study employed a mixed-methods approach using an explanatory sequential framework, as outlined by Creswell and Plano Clark (2018). This approach involved collecting and analyzing quantitative data first, followed by qualitative data to provide deeper insight into the phenomena under investigation. The quantitative component utilized a quasi-experimental design, specifically a non-randomized pre-test and post-test control group design. Intact classes were used, and pupils were not randomly assigned, enabling the assessment of the efficacy of simulation-based instruction on learning fractions. In contrast, the qualitative component provided rich, in-depth information regarding pupils' perceptions and experiences with the instructional strategy.

The rationale for employing this mixed-methods approach was to obtain a comprehensive understanding of simulation-based instruction by both quantifying learning outcomes and capturing students' subjective experiences. The study involved two groups: an experimental group and a control group. A pre-test achievement assessment was administered to both groups to determine baseline performance levels. The experimental group received instruction in fractions using simulation-based strategies, whereas the control group was taught using conventional methods. Following the instructional intervention, both groups completed the same achievement test as a post-test, allowing the researchers to evaluate performance differences attributable to the instructional strategy.

To complement the quantitative findings, qualitative data were collected through semi-structured interviews with selected students from the experimental group. These interviews provided insight into learners' perceptions of simulation-based instruction, including its perceived effectiveness, engagement, and impact on understanding abstract fraction concepts. Collectively, this design allowed for a robust analysis of both the objective outcomes and subjective experiences associated with simulation-based instruction in primary mathematics education.

Sample

The study sample comprised 102 primary school pupils drawn from two intact classes in schools under the State Universal Basic Education Board (SUBEB) located in Abeokuta South Local Government Area, Ogun State, Nigeria. The two schools were randomly selected from a pool of conveniently located schools that met the inclusion criteria of having qualified mathematics teachers and functional ICT infrastructure. The experimental group, which received simulation-based instruction, consisted of 49 pupils, while the control group, taught using conventional lecture methods, included 53 pupils. The mean age of the participants was nine years. All pupils were enrolled in Basic 3 (Grade 3), as the curriculum at this stage aligned with the content required for the study. Additionally, Basic 3 was deemed appropriate because none of the pupils had been previously taught fractions, ensuring that the intervention targeted learners without prior exposure to the topic.

Instrumentation

Two primary instruments were employed for data collection: the Fractions Achievement Test (FAT) and the Students' Perception Interview Guide for Simulation (SPIGS). The FAT, developed by the researchers, assessed pupils' achievement in fractions and comprised two parts. Part A collected demographic information, while Part B consisted of 20 multiple-choice items (A, B, C, D). The test items were aligned with the behavioral objectives of the lesson plans used during the intervention and addressed the knowledge, comprehension, and application levels of Bloom's taxonomy.

The SPIGS, a semi-structured interview guide, was administered exclusively to the experimental group to gather qualitative data on pupils' perceptions of simulation-based instruction. Similar to the FAT, SPIGS consisted of two parts: Part A collected demographic information, and Part B included five open-ended questions designed to explore students' experiences, engagement, and perceptions of learning fraction concepts through the simulation-based approach.

Validity and Reliability of the Instruments

The instruments underwent face and content validation by a panel of expert mathematics teachers with experience in primary school instruction and participation in Common Entrance Examination marking. Additionally, test development experts reviewed the instruments to ensure alignment with lesson objectives, logical item organization, and comprehensive conceptual coverage. The validation process also confirmed that all items were grammatically accurate, precise, and suitable for the comprehension level of the pupils.

To establish reliability, the instruments were piloted with 26 students from a school with characteristics similar to those of the study population. After a two-week interval, the test was re-administered to the same students. Reliability was determined using the test-retest method, yielding a coefficient of 0.86, as calculated with IBM-SPSS version 23, indicating high reliability. The SPIGS was also subjected to face and content validation by two experienced mathematics teachers and piloted with three students to refine item clarity and ensure comprehensibility. Inter-rater reliability was not established for SPIGS because the qualitative data consisted of relatively straightforward, short responses from primary school pupils, which were coded by the researcher with extensive familiarity with the study context and objectives.

Data Collection

Data collection commenced with the administration of the pretest (FAT) to both experimental and control groups to establish baseline performance levels. All 102 pupils from the two sampled schools participated in the pretest to assess their initial knowledge of fractions. Following this, the experimental group received six weeks of simulation-based instruction, while the control group was taught the same content using conventional lecture methods without technological integration. Both groups received instruction for the same duration and covered identical content.

At the conclusion of the six-week intervention, both groups completed the posttest, which was identical to the pretest. Quantitative data were analyzed using Analysis of Covariance (ANCOVA), with pretest scores as covariates, to determine the effect of simulation-based instruction on students' achievement. Complementing the quantitative data, qualitative data were collected through semi-structured interviews with selected students from the experimental group. The interviews focused on students' perceptions of using simulation-based instruction to learn fractions. Each interview was recorded, transcribed, and analyzed using thematic analysis to identify recurrent themes (Braun & Clarke, 2019). The data collected was analyzed using thematic analysis to identify themes.

Treatment Procedures for the Experimental Group

The intervention for the experimental group was designed around a structured simulation-based instructional strategy to enhance pupils' understanding of fractions as shown in Figure 1. The approach was implemented for six weeks, following a five-step sequence emphasizing visual representation, interaction, and application of fraction concepts through simulation. This five-step simulation-based instruction was implemented consistently throughout the six-week intervention and aligned closely with the curriculum content for Basic three pupils on fractions.

1. **Step 1**: Before the commencement of formal instruction, the pupils were introduced to the concept of simulation as a learning tool. The teacher initiated this by briefly discussing pupils' prior experiences with sharing and division in everyday contexts (e.g., sharing food, toys, or books). This was followed by a short simulation clip that visually illustrated the idea of "part of a whole"

using everyday objects like cakes and fruits. Pupils were asked to pay attention and describe what they observed, thus activating their prior knowledge and preparing them for the lesson.

2. **Step 2:** Pupils were grouped based on their academic ability and familiarity with digital devices. Using a computer and projector (where available), the teacher presented step-by-step simulations of basic fraction concepts such as 1/2, 1/3, and 1/4 using dynamic visual models. Pupils observed these simulations, answered guiding questions, and engaged in predicting outcomes. This step emphasized teacher-led visual demonstration to foster foundational understanding.
3. **Step 3:** The pupils were then allowed to interact directly with the simulation tools through guided practice. They manipulated on-screen models, such as fraction bars and virtual food items, by matching, dragging, and identifying different fractions. The teacher monitored pupils' interactions, clarified errors, and reinforced key mathematical vocabulary. Pupils verbalized their thinking and described their actions using terms like numerator and denominator.
4. **Step 4**: Pupils engaged in more advanced simulation tasks that involved solving contextual problems collaboratively. Activities included combining simple fractions, identifying equivalent fractions, and solving real-life sharing problems using the digital simulation interface. Each group shared their findings with the class, and the teacher used this as an opportunity to clarify misconceptions and emphasize correct mathematical reasoning.
5. **Step 5**: The teacher presented a brief lesson recap using a summary simulation video and provided a short reflective activity to consolidate learning. Pupils received a summary message via WhatsApp on their parents' phones containing key points and links to interactive fraction games and recap videos. In subsequent weeks, pupils in rotating groups were tasked with preparing and sharing these digital summaries, promoting technological engagement and learner autonomy.

Figure 1. Treatment for the experimental group

Treatment Procedures for the Control Group

Students in the control group also received four hours of instruction on fractions per week for six weeks. The lessons were delivered by their regular subject teachers using the conventional teaching method, with no incorporation of simulation-based instructions. This traditional approach relied primarily on class discussions and direct instruction. This approach aimed to ensure that students understood the basic principles of fractions through traditional, non-digital classroom interactions. The instructional process followed a structured five-step format to guide classroom activities.

1. **Step 1:** The teacher introduced the concept of fractions and explained the lesson's objectives.
2. **Step 2:** Verbal explanations and board illustrations presented key concepts and examples.

3. **Step 3**: Connections were drawn between students' prior knowledge and the new concepts to support understanding.
4. **Step 4**: The teacher summarized the lesson content and reinforced the major points discussed.
5. **Step 5:** Students were encouraged to ask questions about the teacher's address to clarify doubts.

Immediately after the completion of the intervention phase, a post-test using the Fractions Achievement Test was administered to the control and experimental groups as shown in Figure 2. The purpose of this assessment was to evaluate the effectiveness of the different instructional strategies applied during the intervention by measuring the students' levels of achievement.

Figure 2. Conventional method for the control group

RESULTS AND DISCUSSION

The primary objective of this study was to examine the efficacy of simulation-based instruction in teaching fractions in primary mathematics. Prior to data analysis, the dataset was tested for normality and homogeneity of variance to ensure suitability for parametric analysis. The Shapiro-Wilk test confirmed normality, and Levene's test verified homogeneity of variance, indicating that the assumptions for ANCOVA were met as presented in Table 1. Subsequently, a one-way ANCOVA was conducted on the achievement test scores, with teaching method as the independent variable and posttest scores as the dependent variable, controlling for pretest scores.

Research Question One

The first research question addressed whether simulation-based instruction effectively enhances pupils' academic performance in fractions. Descriptive statistics as shown in Figure 3 indicated that pupils in the experimental group, who received simulation-based instruction, achieved higher mean scores (Mean = 16.1, SD = 3.69) compared to their counterparts in the control group, who were taught using conventional methods (Mean = 10.6, SD = 2.50). These findings suggest that simulation-based instruction significantly improves learners' understanding and mastery of fractions, supporting prior research that highlights the benefits of interactive and visual learning tools in mathematics (Smith & Johnson, 2020; Kibirige & Tsamago, 2019).

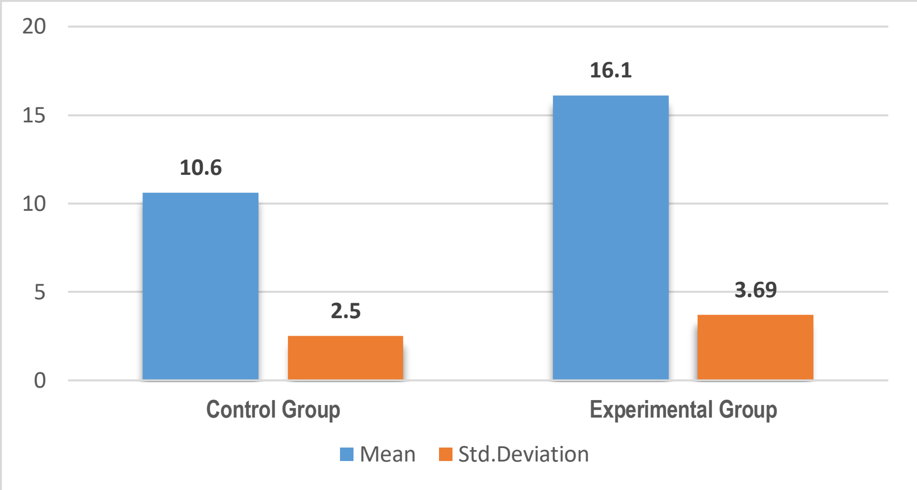

Figure 3. The mean scores and standard deviation of the students' performance in the control and experimental groups

Research Question Two

The second research question explored students' perceptions regarding the use of simulation-based instruction for learning fractions. Qualitative data were collected through semi-structured interviews with seven participants (n = 7) from the experimental group. Thematic analysis was conducted following transcription and systematic coding of responses as summarized in Table 1. Analysis revealed that students found simulation-based instruction engaging, enjoyable, and instrumental in improving their understanding of fractions. Participants noted that simulations helped them visualize fraction concepts, comprehend the challenges associated with fractions, and remain attentive during lessons. Several students emphasized that using simulations made learning more interactive and enjoyable, suggesting that this approach could enhance teaching practices if adopted more broadly.

Table 1. Summary of the findings from the interview on students' perceptions of using simulation-based instruction in learning fractions. N = (7)

Theme	Frequency	Supporting Quotes	Additional Participant Input	Interpretation
Improved Understanding Through Simulation (Do you think understanding mathematics is easier now?)	7/7	Pupil A (10 years, boy): "Yes, the videos helped me understand everything. I wish all teachers used this to teach us."	All pupils (7/7) confirmed improved understanding of fractions.	100% of pupils reported that simulations made mathematics easier to understand.
Benefits of Repetition and Visuals (How does watching videos or demonstrations help you learn better?)	6/7	Pupil B (10 years, girl): "I love the videos. I can watch them many times… it will help me to understand better when I continue to watch!"	Pupils A, C, D, E, F, G	86% of pupils valued repeated viewing and visuals for better recall and comprehension.
Increased Engagement and Fun (Are pictures and	6/7	Pupil D (10 years, boy): "Yes, I love this way of	Pupils A, B, C, E, G	86% of pupils found lessons with simulation

Theme	Frequency	Supporting Quotes	Additional Participant Input	Interpretation
diagrams easier to remember than just words or numbers? / Did you find learning this new way fun and interesting?)		learning because I can understand and remember better!" Pupil C (9 years, girl): "I enjoyed the class because the teacher used lots of pictures and diagrams."		more fun, exciting, and easier to remember than traditional methods.
Preference for Continued Use (Would you like to continue learning like this in the future?)	5/7	Pupil E (10 years, girl): "Can we learn other subjects like this? This is the best way to learn!"	Pupils A, B, C, D	71% of pupils wanted simulation-based learning extended to other subjects.
Blended Learning Preference (Do you love watching videos or prefer your teacher to teach you?)	4/7	Pupil F (10 years, boy): "No, I like watching videos and having my teacher in class too."	Pupils B, C, D	57% of pupils preferred a balance between teacher-led instruction and simulation videos.
Attention and Focus (Does simulation make you pay attention during the class?)	7/7	Pupil G (9 years, girl): "This method helped me pay more attention in class."	All pupils (7/7)	All participants confirmed that the simulation attracted their attention and sustained classroom focus.

The integration of quantitative and qualitative findings indicates that simulation-based instruction not only improves measurable academic outcomes but also positively influences learner engagement, motivation, and conceptual understanding. These results align with constructivist learning theories, which posit that learners benefit from interactive, context-based experiences that allow them to actively construct knowledge (Piaget, 1970; Vygotsky, 1978). Overall, the findings underscore the pedagogical value of simulation-based instruction in facilitating comprehension of complex mathematical concepts, particularly fractions, at the primary school level.

Hypothesis One

The first hypothesis examined whether there was a statistically significant difference in the achievement of students taught fractions using simulation-based instruction compared to those taught using the conventional lecture method. The results of the ANCOVA, presented in Table 2, indicated a statistically significant difference between the experimental and control groups, $F(1, 99) = 50.70$, $p < .05$. The R^2 value demonstrated that the teaching method accounted for 51% of the variance in students' posttest performance, while the partial eta squared indicated that 50% of the observed variance in academic achievement could be attributed to the intervention.

These findings suggest that students in the experimental group, who received simulation-based instruction, performed significantly better in understanding fractions than their peers in the control group, who were taught using conventional methods. This quantitative evidence is further supported by the qualitative data, which revealed that pupils found fractions easier to understand and reported improved comprehension and engagement when learning through simulation-based activities. Collectively, these results confirm the effectiveness of simulation-based instruction in enhancing primary school students' conceptual understanding and academic performance in fractions.

Table 2. Showing the significant difference in the performance of the two groups

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Pn2
Corrected Model	998.34a	2	499.17	50.70	.00	.51
Intercept	893.36	1	893.38	90.74	.00	.47
Group Pretest	998.34	2	499.17	50.70	.00	.51
Error	974.68	99	9.85			
Total	20752.00	102				
Corrected Total	1973.02	101				

R Squared = .506 (Adjusted R Squared = .496)

Discussion

The first research question examined whether simulation-based instruction could effectively enhance students' academic performance in mathematics compared to traditional teaching methods. The findings of this study indicate that students taught fractions using simulation-based instruction achieved significantly higher scores (M = 16.1, SD = 3.69) than those in the conventional lecture group (M = 10.6, SD = 2.50), demonstrating a statistically significant improvement in understanding and performance. This result is consistent with prior studies by Bıçak (2019) and Talan (2021), which reported the successful use of simulation techniques for teaching complex, abstract, and challenging topics. Similarly, Akinsola and Animasahun (2007) observed that simulation environments enhance both students' academic performance and attitudes toward mathematics. In other disciplines, Umoke and Nwafor (2014) found that simulated instructional approaches led to higher achievement in biology compared to conventional methods, while Ojo (2020) reported that pupils exposed to computer simulations performed better in basic science than those taught using lectures. Variations across these studies may reflect differences in the design of simulation tools, subject matter, intervention duration, and instructional implementation strategies (Mthembu et al., 2025).

The second research question explored students' perceptions of using simulation-based instruction to learn fractions. The qualitative findings revealed that pupils perceived simulations as engaging, interactive, and effective for understanding abstract mathematical concepts. Students reported that simulations helped them visualize fractions, facilitating deeper comprehension and application to real-life contexts. These findings are supported by Olalekan (2016), Fallon et al. (2021), Nxumalo-Dlamini and Gaigher (2019), and Batamuliza et al. (2024), who highlighted that simulation promotes active learning, learner engagement, and self-directed exploration within a safe, risk-free environment.

The study's single hypothesis examined whether there was a statistically significant difference in achievement between students taught fractions using simulation-based instruction and those taught via conventional lecture methods. The results confirmed a significant improvement in the experimental group, aligning with research by Cents-Boonstra et al. (2021) and Hu (2024), which noted that traditional theoretical teaching often demotivates students due to challenges in connecting content to real-world applications. Furthermore, studies by Arıcı and Yılmaz (2020), Kibirige and Tsamago (2019), and Wen et al. (2020) corroborate the positive impact of simulation strategies on learning outcomes.

However, some studies comparing simulation to alternative instructional methods have reported no significant differences (Bıçak, 2019; Binsuwaidan et al., 2025). Such discrepancies may be attributed to variations in simulation design, implementation strategies, and learning activities. While the present study demonstrates that simulation-based instruction significantly enhances the academic performance of Grade 3 pupils in Ogun State, Nigeria, caution is warranted in generalizing these findings to other regions, grade levels, or school contexts. The novelty effect may have contributed to the observed improvement, as pupils might have performed better due to the new and engaging nature of the method. Future research should explore the long-term impact of simulation-based instruction to determine whether the observed benefits are sustained beyond initial exposure and across diverse educational settings.

CONCLUSION

This study investigated the efficacy of simulation-based instruction as a pedagogical strategy for enhancing Grade 3 pupils' academic performance in fractions. The findings indicate that students exposed to simulation-based instruction outperformed their peers taught using conventional methods, suggesting that simulations can serve as an effective instructional tool for primary mathematics education.

However, several limitations should be noted. The study was conducted with a relatively small sample in Nigeria, which restricts the generalizability of the findings to other regions, grade levels, or educational systems. Cross-regional studies with larger and more diverse samples are recommended to validate and extend these results. Additionally, the observed improvement may have been influenced by the novelty effect, whereby pupils were motivated by the new and engaging nature of the simulation technology; future research should explore the sustainability of these benefits when simulation-based instruction is integrated into routine classroom practice.

The use of intact classes also limited randomization and may have introduced sampling bias. Subsequent studies could strengthen generalizability by employing random assignment or larger samples. Furthermore, while the experimental group's teacher received training on simulation-based instruction, the control group's teacher taught using conventional methods. Differences in teaching quality and experience may have contributed to the outcomes, making it difficult to fully isolate the effect of the instructional strategy from teacher influence.

Despite these limitations, the study underscores the potential of simulation-based instruction to enrich mathematics teaching, particularly by making abstract concepts more accessible. To maximize its impact, careful contextualization is required, including adequate teacher professional development and provision of digital infrastructure such as computers, internet access, and projectors. Broader research across diverse educational settings is essential to establish the long-term effectiveness and practical feasibility of simulation-based instruction in primary mathematics.

Acknowledgments

The authors sincerely appreciate the support and cooperation of the pupils who participated in this study and their teachers, headteachers, and staff members of the State Universal Basic Education Board in

Abeokuta, Ogun State, Nigeria. We also extend our gratitude to our colleagues for their insightful comments and valuable suggestions, which contributed to the success of this research.

Declarations

Author Contribution	:	OTO: Conceptualization, Writing, Original Drafting, Methodology, Validation, Data Curation, Data Analysis, Review, and Editing. TJ: Conceptualization, Supervision, Review & Editing, Formal Analysis, Methodology, and Funding Acquisition.
Funding Statement	:	The research did not receive any funding.
Conflict of Interest	:	The authors declare no conflict of interest.
Additional Information	:	Additional information from the corresponding author is available for this paper.

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