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# Gender-Based Analysis of Generative AI's Effectiveness in Enhancing Algebra Achievement in Senior Secondary Schools in Funtua Educational Zone, Katsina State

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**Abstract**
This study explored the impact of Generative Artificial Intelligence (GenAI) on algebra performance among male and female senior secondary school students in the Funtua Educational Zone, Katsina State, Nigeria. A quasi-experimental design with a one-group pretest-posttest approach was employed. The study targeted 5,245 SS2 Mathematics students across 22 public secondary schools in the zone. A total of 61 students were randomly selected from one co-educational school among the 18 available. The experimental group, comprising both male and female students, received Algebra instruction using GenAI-based teaching methods. Data collection was conducted using the Algebra Performance Test (APT), which was validated by experts from Ahmadu Bello University, Zaria, and achieved a reliability coefficient of 0.69 through Pearson Product-Moment Correlation (PPMC). The study was guided by one research question and one null hypothesis. The research question was analyzed using Mean, Standard Deviation, and Mean Difference statistics, while the hypothesis was tested using a Paired Sample t-test at a 0.05 significance level. Results indicated no significant gender-related differences in algebra performance within the experimental group. The study concludes that GenAI is an effective and inclusive instructional tool for enhancing algebra learning among secondary school students. It is recommended that Mathematics teachers incorporate Generative Artificial Intelligence into their teaching strategies to enhance students' comprehension of complex mathematical concepts such as Algebra.

**Keywords:** Generative Artificial Intelligence (GenAI), Algebra, Academic Performance, Gender

## Introduction

Mathematics is a core subject taught at all educational levels—basic, secondary, and tertiary—in Nigeria. Its importance spans across multiple areas of life, as highlighted by Olanrewaju (2023). De Vera and Balgua (2023) described mathematics as the essential foundation of science and technology. In Nigeria's formal education system, the subject plays a crucial role in imparting scientific and mathematical knowledge, developing critical thinking, fostering positive attitudes, and equipping students with essential problem-solving skills. Blåsjö (2021) further emphasized that mathematics underpins all scientific disciplines, as no scientific field can progress without mathematical validation. Agah (2020) highlighted the interconnected nature of mathematics, science, and technology, asserting that without mathematics, science would lack its foundation, and without science, technological advancement would be impossible. Consequently, modern society's development hinges on these relationships. Mathematics is thus a universal subject taught globally, with its medium of instruction varying based on each nation's official language (Acharya et al., 2021). Hillmayr et al. (2020) highlighted mathematics as a critical tool for advancing scientific and technological development. No nation can achieve progress in these areas without prioritizing mathematics education, which equips learners with the ability to understand and interpret complex scientific and technological concepts. The National Policy on Education of the Federal Republic of Nigeria (FRN, 2013) designates mathematics as a compulsory subject for all students, regardless of discipline, gender, or ability, requiring them to pass it at the credit level, particularly at the secondary school level. To achieve the objectives of mathematics education, Nigeria must adopt modern teaching innovations, supported by skilled mathematicians who can accelerate the realization of educational goals. Despite its


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importance, research by Ndidi and Effiong (2020) and Eyong et al. (2020) reveals persistent poor performance in mathematics among Nigerian students. Contributing factors include insufficient teaching resources, mathematics anxiety, ineffective instructional strategies, and inadequate classroom facilities. In response, researchers such as Pattier (2021) and Nabayra (2022) have recommended the use of modern teaching methods, including the integration of Generative Artificial Intelligence (GenAI) as a teaching aid to enhance learning outcomes.

Generative Artificial Intelligence (GenAI) has become a powerful tool across numerous sectors, including education, healthcare, and the creative industries. Recent systematic reviews have explored its applications and implications, offering insights into its evolving role and future potential. In education, Ogunleye et al. (2024) conducted a systematic review of GenAI's integration in higher education, analyzing 355 relevant studies. They identified a notable lack of guidelines for effectively embedding GenAI into teaching and learning practices and emphasized the need for interdisciplinary research to develop comprehensive frameworks and policies for educators and stakeholders. Sengar et al. (2024) analyzed the progress and applications of Generative Artificial Intelligence (GenAI) across various fields, emphasizing its significant role in language generation, image translation, and interdisciplinary innovation. Their study also highlighted the necessity of implementing Responsible AI principles, stressing ethical considerations to promote the sustainable and accountable development of generative models. Collectively, these findings underscore the transformative capabilities of GenAI and the need for well-defined guidelines and ethical standards for its use. Similarly, McIntosh et al. (2023) explored the evolving landscape of GenAI, examining advancements such as Google's Gemini and the anticipated OpenAI Q* project. Their research delved into the computational complexities, scalability, and practical applications of these technologies across industries like healthcare, finance, and education. They also discussed the academic challenges arising from the growing presence of AI-generated content, emphasizing the importance of ethical, human-centered AI development. When utilized effectively, GenAI has the potential to significantly improve students' academic performance.

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Academic performance refers to the level of achievement demonstrated by students in assessments, typically measured by comparing their test or examination scores to those of peers at the same educational level. Jomuad and Paclipan (2020) described academic performance as a student's current scholastic standing, while Wang et al. (2020) defined it as the quality of students' learning outcomes, reflected through their examination scores. Ariastuti and Wahyudin (2022) further highlighted that academic performance measures students' learning progress over time. Gender is another critical variable in this study, defined as the set of characteristics distinguishing males and females, which may include biological differences, social roles, and identity (Shahzad et al., 2021). Siddiqi and Shafiq (2017) viewed gender as a socio-cultural construct that assigns roles, attitudes, and expectations to each sex. Rodriguez et al. (2020) identified gender as a significant factor influencing Mathematics performance, noting that societal perceptions of Mathematics as a male-dominated subject can lower female students' motivation and contribute to a performance gap favouring male students. Consequently, female students often demonstrate lower achievement in Mathematics and related fields.

This study aims to investigate the extent to which Generative Artificial Intelligence (GenAI) impacts algebra performance among male and female SS II students in the Funtua Educational Zone, exploring whether significant gender-based differences emerge when students are taught using GenAI-based instructional methods. The Technology Acceptance Model (TAM), introduced by Davis (1989), is a widely acknowledged framework for examining how individuals adopt and utilize new technologies. It identifies two primary factors influencing acceptance: perceived usefulness and perceived ease of use. Perceived usefulness refers to the degree to which users believe a technology will enhance their performance or provide concrete benefits, such as improved learning outcomes, greater efficiency, or increased productivity. In an educational context, for instance, students are more inclined to embrace Generative Artificial Intelligence (GenAI) if they perceive it as a tool that enhances their academic performance and learning experience. Perceived ease of use, on the other hand, pertains to how intuitive and effortless users find a technology. If students consider GenAI tools user-friendly and seamlessly integrable into their study routines, they are more likely to engage with and adopt them consistently. TAM suggests that both perceived usefulness and ease of use are influenced by external factors, including prior technological experience, access to technical support, and the overall design and functionality of the tool. These perceptions shape users' attitudes toward the technology, which subsequently affects their intention to use it, ultimately determining whether adoption occurs. Over time, TAM has been expanded to incorporate additional


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variables such as social influence, facilitating conditions, and trust, all of which further refine users' interactions with technology.

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In the context of education, TAM provides critical insights into how students, educators, and administrators assess and adopt technological innovations. When applied to the adoption of GenAI in teaching and learning, TAM suggests that students are more likely to engage with AI-driven educational tools if they perceive them as both beneficial for learning and easy to use. This understanding can guide the design and implementation of GenAI tools to promote higher engagement and better learning outcomes.

**Statement of the problem**

Mathematics is fundamental to advancements in science, technology, and the socio-economic growth of any nation. Despite its significance, students in Nigeria continue to struggle with Mathematics, particularly algebra, as consistently reported by the West African Examination Council (WAEC) and the National Examinations Council (NECO). Several factors contribute to this persistent underachievement, including ineffective teaching strategies, inadequate instructional materials, mathematics anxiety, and limited access to modern technological tools that could enhance learning experiences. One area that remains relatively unexplored is the potential of Generative Artificial Intelligence (GenAI) in improving mathematics performance. GenAI offers advanced capabilities such as generating interactive instructional content, providing personalized learning feedback, and facilitating dynamic problem-solving approaches. These features could revolutionize algebra instruction; however, its adoption and effective integration into Nigerian secondary schools remain minimal, with limited empirical evidence on its impact on student performance.

Moreover, gender disparities in Mathematics achievement have been a long-standing issue. Studies suggest that female students often perform below their male counterparts, potentially due to societal stereotypes, low self-efficacy, and perceived biases in Mathematics education. This raises an important question: Can GenAI create an inclusive learning environment that bridges the gender gap in Mathematics performance? To address these concerns, there is a need to evaluate the effectiveness of GenAI as a teaching tool for enhancing algebra performance among senior secondary school students in the Funtua Educational Zone, Katsina State, Nigeria. Specifically, this study aims to assess whether GenAI can improve learning outcomes for both male and female students while fostering gender equity in Mathematics achievement. By investigating the role of GenAI in Mathematics education, this research seeks to provide valuable insights for educators, policymakers, and stakeholders on leveraging modern technological innovations to enhance Mathematics instruction and bridge gender performance gaps in Nigerian secondary schools.

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**Objectives of the Study**

The objectives of this study are to:

1. examine the effect of Generative Artificial Intelligence (GenAI) on the performance of SS II Mathematics students in algebra by gender

**Research Question**

The following research questions guided the study;

1. What is the difference between the mean performance scores of male and female SS II students taught algebra using Generative Artificial Intelligence (GenAI)?

**Hypothesis**

The following null hypotheses were formulated and tested at $p \leq 0.05$ $level$ of significance:

**HO₁:** There is no significant difference between the mean performance score of male and female SSII students taught algebra using Generative Artificial Intelligence (GenAI).

**Methodology**

This study adopts a quasi-experimental design with a single experimental group, utilizing a pre-test and post-test approach to evaluate the impact of Generative Artificial Intelligence (GenAI) on students' algebra performance. To maintain a natural classroom setting, intact classes were used. The study targeted all Senior Secondary School II (SSII) students across 22 public secondary schools in the Funtua Educational Zone, Katsina State, with a total population of 5,245 students. These schools consisted of 18 co-educational institutions and four single-sex schools (two for males and two for females), all under the ownership of the Katsina State Government and operating as either day or boarding schools. A simple random sampling technique (balloting


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method) was employed to select one co-educational senior secondary school from the 18 available. From this school, an intact class of 61 SSII students was chosen as the experimental group. To establish a baseline for academic performance in algebra, a pre-test was administered to the students before the intervention. The experimental group was subsequently taught algebra using GenAI-based instructional tools. After the intervention, a post-test was conducted to assess the effectiveness of GenAI in enhancing algebra learning. The pre-test and post-test scores were compared to determine the impact of the intervention. Additionally, gender-based performance variations were analyzed to explore whether GenAI influenced male and female students differently. To measure algebra proficiency, the researcher developed the Algebra Performance Test (APT), a 40-item multiple-choice assessment aligned with key algebra concepts. The test was structured using a table of specifications based on Bloom's Taxonomy (1970), ensuring comprehensive coverage across cognitive domains, including knowledge, comprehension, application, and analysis. To validate the APT, it underwent rigorous evaluations for construct, criterion, and content validity by a panel of professors from the Department of Science Education at Ahmadu Bello University, Zaria. This expert review process confirmed that the test aligned with the objectives of the Senior Secondary School Mathematics curriculum and effectively measured the intended constructs. A pilot study was conducted at Government Day Senior Secondary School Funtua, which was part of the study's population but not included in the final sample. A total of 30 SSII students participated in this phase to assess the test's clarity, difficulty level, and overall effectiveness. The reliability of the APT was determined using Pearson Product-Moment Correlation (PPMC), with data analysis performed through SPSS software (Version 20.0). The resulting reliability coefficient ($r = 0.69$) indicated a strong positive correlation between repeated test administrations, confirming the APT as a dependable instrument for assessing students' algebra performance in this study.

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**Results**

Results obtained from the data collected were analyzed as follows:

**Research Question One:** What is the difference between the mean performance scores of male and female students taught algebra using Generative Artificial Intelligence (GenAI)?

To address the second research question, the post-test scores from the Algebra Performance Test (APT) for both the experimental and control groups were analyzed using mean and standard deviation (SD). A summary of the findings is presented in Table 1.

**Table 1**

**Mean, Standard Deviation Statistics of Posttest APT scores for Male and Female Students in Experimental Group**

| GENDER | N | Mean | STD | Mean difference |
|---|---|---|---|---|
| Male | 34 | 33.00 | 1.74 | 0.03 |
| Female | 27 | 33.03 | 1.87 | |

The descriptive statistical analysis of mean performance scores revealed no significant difference between male and female SSII students taught Algebra using Generative Artificial Intelligence (GenAI). The calculated mean scores were 33.00 for male students and 33.03 for female students. This result suggests that both genders achieved similar academic performance when instructed with GenAI-based methods. The minimal variation in mean scores indicates that GenAI fosters an inclusive learning environment, ensuring equitable academic outcomes for both male and female students in Algebra instruction.

**Testing Null Hypotheses**

**$H0_1$:** There is no significant difference between the mean performance score of male and female SSII students taught algebra using Generative Artificial Intelligence (GenAI).

To evaluate the second null hypothesis, the post-test scores from the Algebra Performance Test (APT) for male and female students in the experimental group were analyzed using an independent samples t-test. A summary of the results is presented in Table 2.


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**Table 2: Summary of Independent Sample t-test of Mean Posttest APT Scores for Male and Female in Experimental Group.**

| GENDER | N | Mean | STD | Mean diff. | Df | t comp. | t crit. | p |
|---|---|---|---|---|---|---|---|---|
| Male | 34 | 33.00 | 1.74 | -0.37 | 59 | -0.080 | 1.96 | 0. 916 |
| Female | 27 | 33.03 | 1.87 | | | | | |

**p > 0.05, t-computed < 1.96 at DF 59**

The independent t-test results revealed no significant difference in the mean performance scores of male and female SSII students taught Algebra using Generative Artificial Intelligence (GenAI). The computed p-value of 0.937 exceeded the 0.05 significance threshold, while the t-value of -0.080 was lower than the critical t-value of 1.96 at df = 59. The mean performance scores were 33.00 for male students and 33.03 for female students, indicating similar academic achievement across genders. Therefore, the null hypothesis, which states that there is no significant difference between the performance of male and female SSII students taught Algebra with GenAI, is accepted. These findings suggest that GenAI fosters an inclusive and gender-neutral learning environment, ensuring equitable academic outcomes for both male and female students in Algebra instruction.

**Discussion**

The study's findings reveal no significant difference in performance between male and female students when taught using Generative Artificial Intelligence (GenAI), indicating that the GenAI-based instructional approach is equally effective for both genders. This result aligns with Møgelvang et al. (2024), who reported that boys in mixed-gender learning environments did not outperform their female peers. Similarly, research by Gesser-Edelsburg et al. (2024) and Daher and Hussein (2024) found that gender did not significantly influence academic performance among secondary school students exposed to GenAI. However, contrasting findings were reported by Diao et al. (2024), who observed that male students demonstrated higher achievements in various academic areas compared to their female counterparts when utilizing GenAI-based learning tools.

**Conclusion**

This study concludes that integrating Generative Artificial Intelligence (GenAI) significantly improves male and female students' academic performance in Algebra. The findings show that both genders achieved higher mean scores with GenAI compared to conventional teaching methods, demonstrating its effectiveness for all students. These results highlight GenAI's potential as a powerful educational tool for enhancing learning outcomes and promoting academic equity across genders.

**Recommendations**

Based on the findings of this study, the following recommendations are made:

1. Integration of GenAI in Mathematics Curricula: Schools and educational policymakers should consider incorporating Generative Artificial Intelligence (GenAI) tools into the Mathematics curriculum, particularly for teaching Algebra, to enhance students' academic performance across both male and female learners.
2. Teacher Training on GenAI Utilization: Continuous professional development programs should be organized to train Mathematics teachers on the effective use of GenAI in the classroom. This will ensure teachers are equipped with the necessary skills to maximize the potential of AI tools in fostering equitable learning outcomes.
3. Further Research on Long-Term Impact: Educational researchers should conduct longitudinal studies to explore the long-term impact of GenAI on students' performance, retention, and interest in Mathematics, focusing on whether its effects remain consistent across different genders and educational levels.

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