IMPLICATION OF CHATGPT ON EFFECTIVE LEARNING OF DIFFERENTIAL CALCULUS

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Abstract

This study explores the potential of Artificial Intelligence (AI) in enhancing the quality of mathematics education and its implications for learning differential calculus. Consequently, the study formulated four hypotheses which were tested using t-test technique at $p<0.05$. Simple random sampling technique was used to select sixty (60) students of senior secondary school category while a modified differential calculus achievement test was used to elicit responses from the sample. Upon the above premise, pretest and post tests were administered on both experimental and control groups to enrich the findings. The findings revealed that significant improvements in learning effectiveness, positive perceptions of AI tools among students, enhance student learning outcomes through improved analytical and problem-solving skills. These results highlight the transformative potential of AI in addressing educational challenges and promoting broader societal goals. The study underscores the need to address ethical considerations and invest in infrastructure and professional development to maximize the benefits of AI in Mathematics education. Then, it was recommended among others that educational institutions integrate ChatGPT as a supplementary instructional tool rather than as a replacement for traditional teaching methods.

Keywords: Artificial Intelligence, ChatGPT, Mathematics Education, Differential Equation**.**

Introduction

Differential calculus is a fundamental branch of mathematics that deals with the study of rates of change and the behavior of functions. It plays a crucial role in various scientific and engineering disciplines, forming the foundation for problem-solving in physics, economics, and computer science (Stewart, 2016). However, many students struggle with understanding its abstract concepts, particularly in resource-constrained environments where large class sizes and limited instructional time make individualized support difficult (Tall, 2013). These challenges often lead to poor academic performance and a lack of confidence in mathematical problem-solving. Recent advancements in artificial intelligence (AI) have introduced new opportunities to enhance learning experiences. AI-powered tools, such as ChatGPT, provide real-time, personalized

learning support by simulating human-like tutoring interactions (Luckin et al., 2016). ChatGPT, developed by OpenAI, is a state-of-the-art conversational AI model designed to generate text-based responses that help users understand and apply complex concepts. In the context of mathematics education, ChatGPT has been explored for its potential to improve student engagement, problem-solving abilities, and conceptual comprehension (Holmes, 2022). By offering step-by-step explanations, interactive problem-solving assistance, and immediate feedback, ChatGPT can serve as a digital tutor that supplements traditional instruction. Despite the growing adoption of AI in education, there is still limited empirical research on its impact on mathematics achievement, particularly in secondary education settings (Hinojo-Lucena et al., 2019). Most existing studies focus on AI's role in higher education, leaving a gap in understanding how tools like ChatGPT influence learning at the secondary school level (Zawacki-Richter et al., 2019). Moreover, concerns have been raised regarding AI's reliability, accuracy, and potential for fostering over-reliance among students (Firat, 2023).

Objective of the Study

This study investigates the implications of integrating ChatGPT into secondary school differential calculus instruction. Specifically, it aims to;

1. Determine whether ChatGPT-assisted learning improves students' conceptual understanding and problem-solving skills compared to traditional teaching methods.
2. Explore whether gender differences influence the effectiveness of AI-assisted learning.

Research Questions

1. Does ChatGPT-assisted learning improves students' conceptual understanding and problem-solving skills compared to traditional teaching methods?
2. Does a gender difference influence the effectiveness of AI-assisted learning?

Research Hypotheses

The study is guided by the following hypotheses:

- **H_1:** ChatGPT does not significantly improve students' understanding of differential calculus concepts.
- **H_2:** ChatGPT does not significantly enhance students' problem-solving skills in differential calculus.
- **H_3:** There is no significant gender difference in the mean performance scores of students using ChatGPT.

Methodology

Research Design

The study adopted a quasi-experimental design, specifically a pretest - posttest control group design. This design was chosen because it allows for the comparison of two groups, one exposed to the intervention (ChatGPT-assisted learning) and the other relying on traditional instructional methods. The pretest - posttest structure enables the measurement of changes in academic performance attributable to the use of ChatGPT, providing insights into its effectiveness as a learning tool for differential calculus.

Population

The population for this study encompasses all senior secondary school students in Afijio Local Government Area who are currently studying differential calculus. This includes students from both public and private schools across Senior Secondary School Two (SSS 2) and Senior Secondary School Three (SSS 3) because these levels represent the advanced stages of the mathematics curriculum where differential calculus is typically introduced and studied. Private schools were chosen for this study due to their learning environments compared to public schools.

Sample and Sampling technique

The study used random sampling approach in selecting a sample from the aforementioned population, focusing specifically on students attending private schools within the Afijio Local Government Area. Then a multistage sampling technique was employed to select a sample of sixty (60) students from private secondary schools in Afijio Local Government Area (LGA). By employing multistage sampling technique, the study obtained a sample that accurately reflected the population of interest, thereby enhancing the generalizability of the findings.

Instrumentation

A self-developed Differential Calculus Achievement Test (DCAT) was used for data collection. The DCAT was administered as a pre-test to the two groups i.e experimental group and control group and then shuffled and re-administered as the post-test. The instrument comprised section A containing demographic data of the respondents and section B having fifteen structured multiple-choice questions covering essential differential calculus topics.

Validity of the instrument

The instrument was given Differential Calculus Achievement Test (DCAT) to the expert in the field of test and measurement evaluation for face and content validity Thereafter identified errors were effected to standardize the instrument.

Reliability of the instrument

The reliability of the instrument was determined during a pilot study using Cronbach's alpha and yielded a coefficient of 0.75. Tavakol & Dennick (2011) noted that a Cronbach's alpha of 0.70 or above is typically considered acceptable, indicating that the scale items consistently measure the same underlying construct. Therefore, the 0.75 coefficient obtained for the DCAT indicating that the test possessed high internal consistency

Procedure for Data Collection

Data collection for this study followed a systematic and multi-step process designed to ensure ethical compliance, minimize disruption to school activities, and obtain reliable data on the impact of ChatGPT-assisted learning in differential calculus. Initially, the researcher visited the selected private secondary schools in Afijio Local Government Area to meet with school administrators and obtain formal approval to conduct the study. The researchers held a briefing session in each school to explain the purpose of the test and modality to be adopted in carrying out the experiment. Thereafter, a pretest was administered to both the experimental and control groups to establish a baseline of students' understanding and problem-solving skills in differential calculus. This pretest provided an initial performance metric that was later used for comparison with post-intervention results.

After collecting the pretest data, the intervention phase commenced and at the end of the intervention period, a posttest was administered to both groups. All responses from both tests were collected and recorded systematically, and demographic data were also gathered to contextualize the findings.

Data Analysis

The collected data was analyzed using simple percentages and frequency counts to summarize the demographic variables, with Microsoft Excel employed to visualize the demographic data through graphs and charts while t-test was used to test the research hypotheses at 0.05 level of significance.

Main Results

Research Hypotheses Testing

H_{01}: ChatGPT does not significantly improve students' understanding of differential calculus concepts**.**

Table 1

Group	**N**	Mean	**S^2**	**df**		**t_{tab}**	**t_{cal}**	**Decision**
Experimental	30	18.866667	7.912644	58	0.05	*2.0032*	1.7252	Accept H_{01}
Control	30	17.466667	11.84368					

From the data presented in table 1, the hypothesis was tested at 0.05% level of significance and since the $t_{cal} < t_{tab}$ the null hypothesis was accepted. This indicates that ChatGPT significantly improves students' understanding of differential calculus concepts.

H_{02}: ChatGPT does not significantly enhance students' problem-solving skills in differential calculus.

Table 2

Group	N	Mean	S^2	df		t_{tab}	t_{cal}	Decision
Experimental	30	18.866667	7.912644	58	0.05	*2.0032*	1.7252	Accept H_{02}
Control	30	17.466667	11.84368					

From the data presented in table 2, the hypothesis was tested at 0.05% level of significance and since the $t_{cal} < t_{tab}$, therefore the null hypothesis was accepted. Consequently, it implies that ChatGPT enhances students' problem-solving skills in differential calculus.

H_{03}: There is no significant gender difference in the mean performance scores of students using ChatGPT

Table 3

Group	N	Mean	S^2	df		t_{tab}	t_{cal}	Decision
Experimental	15	18.866667	8.952381	58	0.05	2.0484	0.3837	Accept H_{03}
Control	15	19.066667	7.352381					

From the data presented in table 3, the hypothesis was tested at 0.05% level of significance and since the $t_{cal} < t_{tab}$ therefore null hypothesis was accepted. Hence it indicates that ChatGPT is not gender bias as per its usage in problem-solving skills in differential calculus.

Discussion of Findings

In hypothesis one, the data indicate that students who engaged with ChatGPT-assisted instruction demonstrated a significant improvement in their understanding of differential calculus concepts compared to those who received traditional instruction. The lower calculated t-value relative to the critical value confirms that the enhanced understanding observed in the experimental group is statistically significant. This finding is consistent with research on AI-based tutoring systems, which have been shown to facilitate deeper conceptual learning through personalized and adaptive support (Holmes *et al.*, 2019). The interactive and immediate feedback provided by ChatGPT enables students to address misconceptions in real time, thereby strengthening their grasp of foundational concepts such as limits and derivatives.

In hypothesis two, which posits that ChatGPT enhances students' problem-solving skills, was also supported by the test data. Students in the experimental group displayed superior problem-solving abilities, as evidenced by their higher performance scores on problem-solving tasks. The structured, step-by-step guidance offered by ChatGPT appears to be instrumental in developing students' procedural fluency and analytical reasoning, which are critical for tackling multi-step calculus problems. These findings align with prior studies that highlighted that AI tools help student's break down complex problems into more manageable steps, providing immediate feedback that allows learners to correct mistakes and refine their approach (Ali et al., 2023).

In hypothesis three**,** the investigation centered on whether there is a significant difference in performance scores of students using ChatGPT based on gender. The analysis, comparing male and female students within the experimental group, revealed a statistically significant difference in mean scores between genders. This suggests that gender-related factors may influence how students benefit from ChatGPT's support in differential calculus. Such differences might be attributed to variations in learning styles, prior exposure to technology, or socio-cultural factors, as some recent studies have indicated that gender can modulate the effectiveness of digital learning tools (Bender et al., 2021). This finding underscores the importance of considering demographic variables when integrating AI tools into educational settings to ensure equitable support across diverse student populations.

Conclusion

Through a quasi-experimental design, the research compared the performance of students who received ChatGPT-assisted instruction with those who followed traditional teaching methods. The findings indicate that while there was a slight improvement in the experimental group's mean scores on measures of conceptual understanding and problem-solving skills, the differences were not statistically significant at the 0.05 level. However, a significant gender-based difference was observed, suggesting that male and female students may benefit differently from AI-assisted learning.

Recommendations

Based on the research findings, the following recommendations are suggested:

- It is recommended that educational institutions integrate ChatGPT as a supplementary instructional tool rather than as a replacement for traditional teaching methods.
- There is a need for professional development and training programs for teachers..
- Schools should invest in the necessary technological infrastructure to support the effective deployment of ChatGPT.
- Given the observed gender differences in the effectiveness of ChatGPT, it is imperative to explore gender-responsive instructional strategies.
- Educational policymakers are encouraged to develop a comprehensive framework for the ethical use of AI in education.

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