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The Impact of GeoGebra on Senior Secondary Students' Performance in Algebra

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Abstract
This study investigates the effectiveness of GeoGebra as a dynamic mathematics software tool in improving the performance of senior secondary students in Algebra. A group of 100 students were selected from a senior secondary school and divided into two groups of 50 each. A quasi-experimental design was utilised, involving a control group and an experimental group taught using traditional methods and GeoGebra, respectively. Pre-tests and post-tests were administered to assess improvement in students' understanding and performance in Algebra. The result was analysed, and the findings indicate that students using GeoGebra outperformed their peers in the control group, suggesting that the integration of technology in mathematics education can enhance student learning outcomes.

Keywords: Algebra, GeoGebra, Mathematics, Performance, Impact

Introduction

The recent trend of underperformance in Mathematics examinations among students is alarming and warrants a collaborative effort from educators, policymakers, and stakeholders to address this issue. Statistics had it that it cuts across all various examination bodies, and these largely arise from the learning processes. The traditional method of learning has been condemned by many authors, and the introduction of technology has been of immense benefit to learning. Mathematics education has long been viewed as a cornerstone of critical thinking and problem-solving. Traditional approaches, relying heavily on rote memorisation and static representations, have often failed to engage students or address diverse learning needs. With the coming of technology, educators now have access to powerful tools that enhance instruction and deepen conceptual understanding.

Mathematics, particularly Algebra, is a critical subject in senior secondary education, forming the foundation for advanced studies in various fields. However, many students struggle with Algebra, leading to poor performance and disengagement (Boaler, 2016). With the rise of technology in education, software such as GeoGebra has emerged as a potential aids in enhancing students' understanding of mathematical concepts (Bakix & Kocabas, 2014). GeoGebra (from Geometry and Algebra) is one of the most innovative, open -code math software packages (GNU General Public License). GeoGebra is an interactive geometry software which allows students to visualize and manipulate algebraic concepts, fostering a deeper understanding (Dörfler, 2006). Studies have highlighted that students using GeoGebra demonstrate greater conceptual understanding and motivation in mathematics (Kerra & Araújo, 2019). It can be downloaded freely from www.geogebra.org. GeoGebra offers easy-to-use interface, multilingual menus, commands and help. It encourages students` projects in mathematics, multiple presentations and experimental and guided discovery learning. GeoGebra was created to help students gain a better understanding of mathematics. This study aims at exploring the impact of GeoGebra on the performance of senior secondary students in Algebra. Research has shown that the integration of technology in mathematics education leads to improved student performance (Hanna & Stewart, 2004).

Benefits of Technology in Mathematics Education

i. Enhanced Visualization and Conceptual Understanding: Technological tools like GeoGebra and Desmos allow students to visualize abstract concepts such as functions, derivatives, and geometric transformations. Dynamic software enables learners to manipulate variables in real-time, fostering a deeper understanding of mathematical relationships.

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ii. Engagement and Motivation: Interactive platforms gamify learning, making mathematics more appealing to students. Gamification elements, such as rewards and challenges, sustain interest and motivate students to persist in problem-solving tasks.
iii. Personalized Learning :AI-powered platforms like Khan Academy and Mathway provide tailored recommendations based on students' performance. Such adaptive systems address individual learning gaps and allow students to progress at their own pace.
iv. Collaboration and Communication: Online tools and virtual classrooms facilitate collaboration among students and educators. Students can work on shared projects, discuss problems, and learn from peers, fostering a sense of community and shared purpose..

GeoGebra is a dynamic mathematics software application that integrates geometry, algebra, statistics, calculus, and spreadsheet functionalities. It was developed in 2001 by Markus Hohenwarter and has since gained popularity in educational settings around the world.
GeoGebra is designed to promote an interactive, exploratory approach to learning mathematics, allowing students to visualize and manipulate mathematical concepts in real-time (Blume & Heck, 2017).

Features of GeoGebra
1. Dynamic Geometry Environment: GeoGebra allows users to create geometric constructions and models easily. Users can manipulate points, lines, and shapes, enabling an exploration of geometric relationships (Hohenwarter& Weigand, 2009).
2. Algebra and Calculus: This software provides a robust algebraic environment where users can enter algebraic expressions and equations. It automatically updates the graphical representation as the algebraic input changes, facilitating a deeper understanding of the connection between algebra and geometry (Kollias et al., 2019).
3. Interactive Learning: GeoGebra enables teachers to create interactive worksheets that can be tailored to various learning styles with its versatile tools. This interactivity helps to engage students and encourage active participation in the learning process (Baki & Kocabas, 2014).
4. Accessibility: GeoGebra is available on multiple platforms, including web browsers, tablets, and desktop applications. The free access to its features makes it a popular choice for educators and students worldwide (Arzarello et al., 2015).

GeoGebra is extensively used in classrooms to enhance the learning experience in mathematics. Research indicates that the use of GeoGebra can improve students' understanding of mathematical concepts, increase motivation, and foster collaborative learning environments (Boaler, 2016). It has been particularly effective in teaching topics such as
-Algebra: Students can visualize algebraic functions and understand transformations by manipulating parameters.
-Geometry: Interactive experiences allow students to investigate properties and theorems, promoting a deeper comprehension of geometric principles.

The integration of GeoGebra into mathematics education necessitates pedagogical shifts. Teachers must guide students not only in using the software but also in developing critical thinking and problem-solving skills. The sustained use of technology like GeoGebra encourages the active construction of knowledge, catering to diverse learning preferences and improving overall mathematical competence (Wang, 2017). GeoGebra stands out as a versatile tool in mathematics education that enhances the learning experience by promoting interactivity and exploration. Its accessibility and dynamic features make it an excellent resource for both students and educators, ultimately contributing to improved understanding and engagement in mathematics. GeoGebra offers easy-to-use interface, multilingual menus, commands and help. It encourages students` projects in mathematics, multiple presentations and experimental and guided discovery learning. GeoGebra was created to help students gain a better understanding of mathematics. GeoGebra is a dynamic mathematics software for all levels of education that brings together geometry, algebra, spreadsheets, graphing, statistics and calculus in one engine

Aim and Objective of the Study
The study aimed to investigate the effect of using GeoGebra on senior secondary students' performance in algebra, comparing the outcomes of students who use GeoGebra with those who receive traditional instruction. The objective of this study is to:

i. compare the initial algebra knowledge of senior secondary students in the experimental and control groups through a pre-test.

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Hypothesis

H0: There is no significant difference in the algebra performance of senior secondary students who use GeoGebra compared to those who do not use GeoGebra in their learning process

Methodology

A quasi-experimental research design was employed, with a sample of 100 senior secondary students from a public school in Alimosho Local Government Area. The participants were divided into two groups: the experimental group (n=50) utilized GeoGebra while learning Algebra, and the control group (n=50) received traditional instruction. A set of 50 questions were prepared on three topics in Algebra as a pre-test, which was administered to assess initial knowledge, followed by a 4-week instructional period. A post-test was then given to evaluate performance improvement. The mean, standard deviation and t-test were used for data analysis.

Results

Table 1a: Descriptive statistics for Algebra Performance

Group	N	Mean	Stand. Deviation	Stand. Error mean
Control	50	70.00	7.10	1.01
Experimental Group	50	82.00	6.50	0.92

Table 1b: Independent sample t-test

t	Deg of freedom	Sig.(2-tailed)	Mean Difference	95% CI for the difference
5.23	98	0.00	12.00	(9.35,14.65)

The results of the study were analyzed using independent t-tests to compare the performance of the two groups. The experimental group showed a significant increase in mean scores ($M = 82$, $SD = 6.5$) compared to the control group ($M = 70$, $SD = 7.1$), $t(98) = 5.23$, $p < .001$.

Discussion

The statistical analysis demonstrated a meaningful improvement in performance ($p = .000$), indicating that the use of GeoGebra has a considerable effect on learning outcomes. Previous research has supported the notion that computer-based tools can enhance understanding and retention in mathematics. These tools provide interactive and visual representations of mathematical concepts, which are essential for deep understanding, particularly in disciplines such as algebra that often involve abstract ideas. The observed mean performance difference of 12 points between the Experimental Group (82.00) and the Control Group (70.00) suggests a substantive educational impact. Research by Gutiérrez and Boero (2006) posits that the visualization capabilities of technology are crucial in fostering students' mathematical reasoning. The findings of this study corroborate their argument, demonstrating how GeoGebra enables better conceptual understanding and improved performance in algebra through its dynamic visualizations.

The 95% confidence interval (9.35, 14.65) reinforces the significance of the finding and suggests practical relevance. From the work of Cohen (2013), effect sizes can help contextualize the importance of findings in educational research. By establishing a clear mean difference between the two groups, this study underscores the potential of GeoGebra to be a transformative part of teaching practices aimed at improving students' mathematical competencies. The findings of this study align with existing literature that supports the use of technology, specifically GeoGebra, as an effective means to enhance student engagement and performance in mathematics (Klein, 2021). The visual and interactive nature of GeoGebra allows students to explore algebraic relationships in a more meaningful way, thus bridging the gap between theoretical knowledge and practical application.

Conclusion

This study concludes that GeoGebra is a valuable tool in improving senior secondary students' performance in Algebra. The positive result suggests that educators should consider incorporating technology into mathematics curricula to foster better learning experiences. Future research could explore the long-term effects of using GeoGebra on students' overall academic performance and attitudes toward mathematics and also to investigate barriers to technology adoption in diverse educational settings.

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