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The Effect of GeoGebra Software on Achievement and Engagement Among Secondary School Students

Hidayat, R.*[1,2], Kamarazan, N. A.[3], Nasir, N.[3], and Ayub, A. F. M.[1,2]

[1]*Faculty of Educational Studies, Universiti Putra Malaysia, Malaysia*
[2]*Institute for Mathematical Research, Universiti Putra Malaysia, Malaysia*
[3]*Faculty of Science and Mathematics, Universiti Pendidikan Sultan Idris, Malaysia*

E-mail: riyan@upm.edu.my
**Corresponding author*

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Abstract

GeoGebra software has been identified as a potential aid in the teaching and learning process. This study aims to examine the impact of GeoGebra software on achievement and enjoyment in the context of the polygon topic. A non-equivalent group pretest-posttest design was utilized, and 60 students were randomly assigned to either the experimental or control group. The data collected was analyzed using descriptive and inferential statistical methods with the assistance of SPSS version 26. The findings revealed that the level of achievement and engagement among Form Two students in the study population was already high regarding the Polygon topic. However, the results demonstrated that students who received instruction utilizing GeoGebra software achieved even higher levels of achievement and engagement than those who experienced traditional teaching methods. As a result, integrating GeoGebra software into the classroom proved to be an effective tool for enhancing student achievement and engagement on the Polygon topic among Form Two students. Finally, we found a significant relationship between the experience of enjoyment and the academic performance of second-year students.

Keywords: achievement; engagement; GeoGebra software; mathematics education; secondary school.

1 Introduction

Learning mathematics is an essential area of knowledge that helps develop students' abilities for more challenging levels in the future [23]. Mathematics education aims to enhance various skills, particularly problem-solving skills in mathematical knowledge, enabling students to function effectively. Abu Bakar et al.[9] recommend incorporating problem-solving into the mathematics education syllabus to enhance students' problem-solving skills. Mathematics teaching and learning in schools must be further optimized to accomplish this educational objective. The primary goal of mathematics education is to facilitate comprehensive student development, including cognitive development. From a pedagogical perspective, the significance of academic achievement lies in its potential to enhance the effectiveness of educational practices. Excelling in mathematics is closely related to teaching methods and the enjoyment that attracts students' interest in mastering the subject. Mathematics learning can become enjoyable for students if every topic studied is made accessible and comprehensible. Enjoyment can be seen as an integral part of academic interest. Enjoyment is often reported as a positive factor in the classroom [8]. Numerous previous studies have demonstrated that enjoyment is crucial to achievement [34].

Previous studies have indicated that students face difficulties when learning mathematics concepts [24] and teachers' readiness using technology [30]. Students often encounter problems in solving tasks related to their conceptual understanding of the area and perimeter of polygons [16]. For example, when a triangle is depicted, students may give it a name based on their interpretation, such as "straight triangle", "upright triangle" or "inverted triangle" without considering the geometric properties of the triangle [18]. The difficulties students face weaken their resilience towards the topic and can lead to a decline in mathematical achievement [22]. Furthermore, these problems are closely related to student enjoyment in the classroom. According to Gopal et al. [19], students' anxiety about learning mathematics was very high, which may lead them to fear the subject and avoid any tasks related to it [26]. Additionally, as stated by Capuno et al. [12], many students consider mathematics to be a boring subject. Students must gain broad knowledge to apply mathematical skills in their daily lives. Moreover, students today have little interest in learning mathematics as they hold negative perceptions about it, considering it extremely difficult and somewhat dull.

Many studies have proven the impact of technology on academic achievement [6]. One software that is increasingly used by teachers and educators nowadays is GeoGebra software. Previous research has found that GeoGebra software can assist students in the teaching and learning process, particularly in terms of its effect on achievement [31]. The findings of conducted studies have shown that using GeoGebra software can help improve students' achievement. A systematic review by Hamzah and Hidayat [20] indicated that using GeoGebra software can enhance achievement, conceptual understanding, motivation, visualization skills, engagement, interest, critical thinking ability, mathematical reasoning, and problem-solving. However, to date, there have been limited studies investigating the effects of GeoGebra software on achievement and enjoyment of the Polygon topic for second-grade students. Recent research has placed significant emphasis on various subjects within mathematics education, including Geometry [11] and Circle and Disc [37]. The current idea's discovery will bridge the existing gap and offer fresh insights into the influence of GeoGebra software on the academic performance and enjoyment of second-grade students when studying the Polygon topic. Therefore, understanding the impact of GeoGebra software on achievement and enjoyment is crucial in helping students comprehend and master the Polygon topic. This study aims to contribute to the literature by examining the use of GeoGebra software on achievement and enjoyment among students on the Polygon topic. Thus, the study intends to assess the effects of GeoGebra software on achievement and enjoyment.

1.1 GeoGebra software

GeoGebra software can assist students in enhancing their achievement. Using GeoGebra software can improve students' visualization skills and contribute to their achievement. GeoGebra software was established in 2001-2002 and has been designed to be highly effective in teaching mathematics [25]. GeoGebra is a software tool that encompasses geometry, algebra, and calculus. GeoGebra software has several advantages in mathematics learning, such as:

(a) The ability to produce geometric drawings quickly and accurately compared to using a pencil and ruler.

(b) Providing animation and the ability to manipulate movements (dragging), which can provide a more apparent visual experience for students in understanding geometric concepts.

(c) It can be used for assessment to ensure that correct drawings are made.

(d) Facilitating teachers and students in observing or highlighting the characteristics used in geometric objects.

In this study, GeoGebra software served as an integrated information technology teaching aid that can assist students in the polygon teaching and learning process.

1.2 Achievement and the impact of GeoGebra software on achievement

The literature extensively supports the beneficial influence of GeoGebra instruction on students' comprehension of geometry principles and their achievements in the subject. Numerous studies confirm that incorporating GeoGebra into geometry teaching results in enhanced learning outcomes and academic success. Academic achievement, which gauges a student's academic performance, is a pivotal aspect of education. GeoGebra software not only enhances academic performance but also fosters student interest in mathematics teaching and learning. Moreover, GeoGebra is versatile and can be applied to various topics like geometry, calculus, and algebra. For instance, Uwurukundo et al. [38] scrutinized the impact of GeoGebra software on the academic performance of secondary school students in 3D Geometry, finding that students who utilized GeoGebra demonstrated improved achievement.

Zulnaidi et al.[40] illustrated that GeoGebra software, known for its user-friendly interface, empowers students to develop their ideas based on specific concepts, thus bolstering their mathematical achievements. Alkhateeb and Al-Duwairi [2] recommended introducing the mobile application GeoGebra to mathematics educators as it enhances students' academic accomplishments and encourages deeper exploration of the world of mathematics, promoting critical and creative thinking skills. Results show that employing the mobile application of GeoGebra software elevates students' comprehension of geometric concepts. Furthermore, Birgin and Acar [10] found that using GeoGebra software for Computer-Supported Collaborative Learning (CSCL) significantly elevated students' performance in exponential and logarithmic functions. Similarly, Birgin and Topuz [11] discovered that CSCL with GeoGebra software made a substantial impact on the geometry performance of seventh-grade students and their retention of what they learned, outperforming traditional textbook-based direct instruction. In summary, a wealth of research in the literature consistently underscores the substantial and positive influence of GeoGebra software on students' geometry comprehension and overall success in mathematics education.

1.3 Enjoyment and the impact of GeoGebra software on enjoyment

Enjoyment is defined differently by experts. Schukajlow [32] argue that students' enjoyment is related to effort and achievement. Enjoyment is one of the positive factors often reported in the classroom [32]. Adelson and McCoach [1] define mathematical enjoyment as the degree to which someone finds pleasure in learning mathematics. Enjoyment can be seen as part of academic interest. A pleasant learning environment can bring joy and motivation to students in their learning [21]. Enjoyment is typically seen as a result of students achieving good academic performance [28]. To date, there have been many past studies discussing the influence of GeoGebra software on learning and its positive impact on student enjoyment [4]. Celen [13] found that using GeoGebra software allows students to make mathematical generalizations and proves that the mathematics teaching and learning process is gratifying. GeoGebra software is more effective than traditional approaches in developing students' visualization skills [5]. Using GeoGebra software can save students time and energy, make lessons more exciting and enjoyable, and provide opportunities for students to create geometric shapes through the software freely.

1.4 Relationship between student enjoyment and students' achievement

Numerous investigations have explored the connection between enjoyment and academic success, highlighting the crucial role that enjoyment plays in promoting positive outcomes in educational settings. The presence of enjoyment in the classroom has frequently been acknowledged as a significant and positive element, as stated in studies conducted by Bakar et al. [8] and Schukajlow [32]. Previous research has consistently shown that enjoyment plays a vital role in academic achievement, as evidenced by various studies such as those conducted by Winarso and Haqq [39]. It is widely acknowledged that when students experience enjoyment in the classroom, their engagement, motivation, and overall learning experience are enhanced. This positive emotional state fosters a favorable learning environment, allowing students to develop a deeper understanding of the subject matter and effectively apply their knowledge. The presence of enjoyment is particularly important in educational contexts, as it has been linked to increased levels of intrinsic motivation. When students find joy and satisfaction in their learning activities, they are more likely to approach tasks with enthusiasm and perseverance. This intrinsic motivation is associated with higher levels of effort, active participation, and a willingness to persist in the face of challenges. When students experience enjoyment in the classroom, they tend to develop a positive perception of the subject matter and a greater appreciation for the learning process. This positive attitude can lead to increased self-confidence, higher levels of self-efficacy, and a greater willingness to explore new concepts and ideas. In summary, by fostering a sense of enjoyment, educators can create an environment that promotes engagement, motivation, and positive attitudes towards learning, ultimately leading to improved educational outcomes for students.

2 Research Objectives

The following includes the objectives of this study:

1. To determine students' achievement and enjoyment of the Polygon topic
2. To determine the difference in achievement mean scores on the Polygon topic between treatment and control groups

3. To determine the difference in enjoyment mean scores between the treatment and control groups
4. To determine the relationship between student enjoyment and students' achievement

3 Research Hypothesis

The following includes the hypothesis of this study:

H_1^0 There is no significant difference in achievement mean scores between the control and treatment groups on the Polygon topic.

H_2^0 There is no significant difference in the level of enjoyment mean scores between the control and treatment groups on the Polygon topic.

H_3^0 There is no significant relationship between student enjoyment and students' achievement on the Polygon topic

4 Methodology

The research design is a method that enables information to be obtained to answer the research questions posed. This study uses a quasi-experimental research design. This design was chosen because it examines the effect of GeoGebra software on achievement and enjoyment. Talib [35] stated that a quasi-experimental design is conducted when the researcher cannot make a random individual selection. This study employs a non-equivalent group pretest-posttest design to examine the effectiveness of GeoGebra software on achievement and enjoyment. It consists of treatment and control groups with similar characteristics. Figure 1 illustrates the design of the pre-test and post-test study, showing the treatment group and the control group. Both groups will undergo the same pre-test and then implement the teaching method. The control group will undergo the traditional methods, while the treatment group will use GeoGebra software. Subsequently, both groups will take a post-test to measure their achievement and enjoyment using the GeoGebra software.

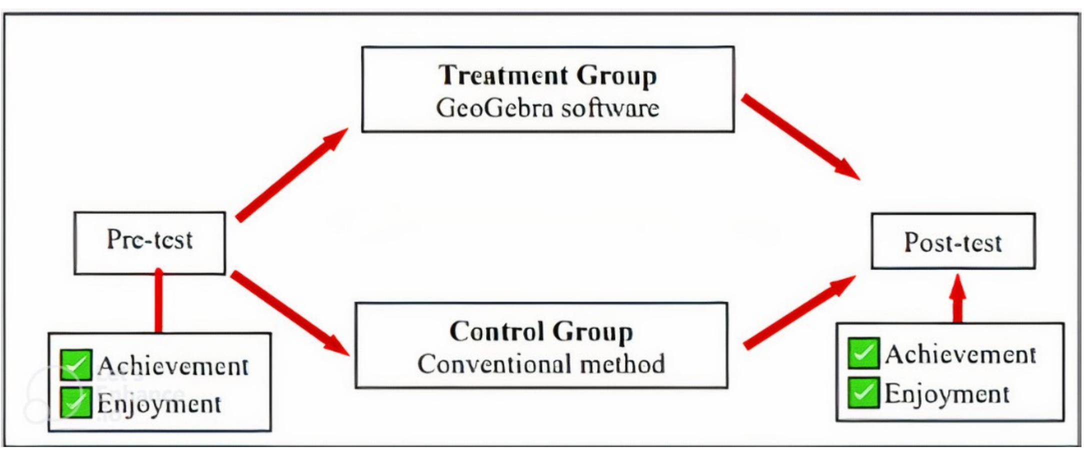

Figure 1: Non-equivalent groups pre-test and post-test.

4.1 The experimental groups

In this treatment group, students have the opportunity to sharpen their skills using GeoGebra software as a dynamic learning tool (Figure 2). They will not only refer to textbooks as a guide but also harness the power of GeoGebra software to bring to life the concepts they have learned from the text. The teacher plays a crucial role as a facilitator, providing necessary guidance and steering focused discussions to guide students through in-depth learning processes. In this group learning environment, students are encouraged to actively interact with their peers. They have the chance to exchange ideas, ask questions, and engage in collaborative discussions that help them gain a deeper understanding of mathematical concepts. Critical thinking and problem-solving processes are emphasized in every teaching session. Each carefully designed teaching session will last for 90 minutes. With this approach, students can absorb information more deeply and experience the benefits of using GeoGebra software along with the guidance of the teacher within the provided time frame.

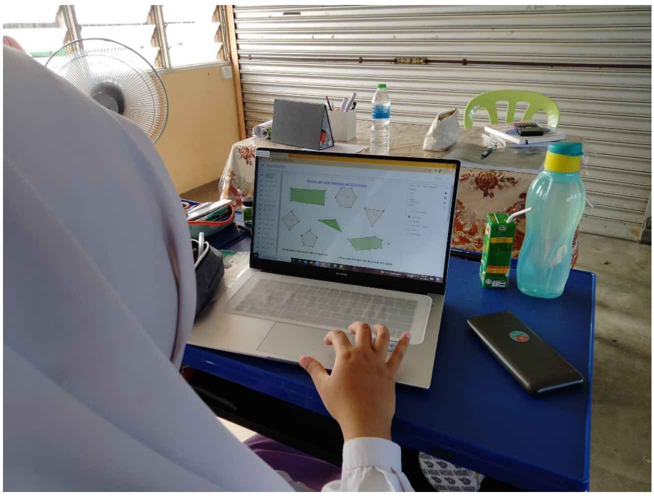

Figure 2: The use of GeoGebra software.

4.2 The control groups

In this control group, the teaching approach is entirely reliant on traditional methods, which limit the learning resources to textbooks as the primary foundation (Figure 3). In this scenario, the teacher assumes the central role as the sole actor in the process of information delivery. Students, in this context, discipline themselves to act as passive recipients, primarily engaging in the act of listening and recording every word conveyed by the teacher. They follow the teacher's explanations closely, with limited opportunities for active interaction or asking questions. Each teaching session in this group is designed to last for a full 90 minutes. Within this timeframe, the traditional teaching approach emphasizes the transmission of knowledge and information by the teacher through oral discourse as the main component of learning. Students are provided with the opportunity to contemplate and absorb this knowledge in a more formal setting. Although this approach can provide a strong structure for information delivery, it may place less emphasis on active interaction or understanding of concepts through practical exercises, as is more commonly found in modern teaching methods.

Figure 3: The use of traditional methods.

4.3 Samples

This study was carried out at one of the Kelantan High School located in Machang. The sampling method used in this study is a random group assignment. Random group assignment is necessary to ensure that there are treatment and control groups [27]. A total of 60 students were involved in the quasi-experimental design to be conducted in this study. All of the samples are female. In this study, one of the Form Two classes in the school was randomly selected as the experiment group (2 Khadijah) and the other (2 Aisyah) as the control group. Each class had 30 students who were involved in the study. Furthermore, before experimenting, the data collection process began by obtaining permission from Universiti Pendidikan Sultan Idris (UPSI). Informed consent was provided by all participants included in the present work.

4.4 Instrument

The instruments used in this study are the Polygon Topic Achievement Test (UPTP) and the Enjoyment Questionnaire. The UPTP is a written test designed to measure the mathematics achievement of Form Two students, specifically on the polygon topic. The test covers the lower secondary mathematics syllabus on the Polygon topic. The UPTP follows a format based on textbook questions and consists of four subjective questions. Using subjective questions from the textbook is motivated by time constraints to ensure that it does not interfere with other teachers' teaching and learning time. The selection of questions considers the cognitive skill levels according to Bloom's Taxonomy, which includes remembering, understanding, and applying [3]. Example questions are 'To examine the attributes of polygons and establish whether a given polygon is regular or irregular' and calculate the values of p, q, and r (Figure 4).

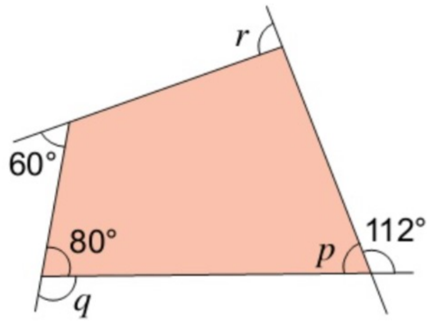

Figure 4: Example of Polygon test.

The research instrument's validity underwent a meticulous evaluation by two seasoned Mathematics teachers, each boasting 5 to 15 years of teaching experience at a secondary school in the Machang District. Their thorough examination was primarily focused on aligning the test's content with the lesson topics, a pivotal component of the validation process. To pinpoint the specific test items that should be retained or removed, the pilot study data was subjected to analysis employing the widely recognized Cronbach's alpha reliability coefficient. Prior to initiating the actual study, a pilot study was conducted using a small sample to assess the research instrument's quality in terms of both validity and reliability, in accordance with Chua's [14] recommendation. These preliminary studies play a crucial role in making necessary adjustments and improvements to the research instruments. A reliable research instrument typically exhibits a Cronbach's Alpha Value of 0.8 or higher, and in this context, the UPTP instrument demonstrated a commendable level of reliability with a Cronbach's alpha value of 0.83. Here are the prepared questions for the students. The Mathematics Enjoyment Questionnaire (MEQ) was used to assess the student's level of enjoyment in mathematics. The MEQ was adapted and modified from a previous study by Keebler et al.[17]. This questionnaire comprises 15 items representing three sub-constructs: enjoyment, enhancement, and involvement. Each item is scored on a scale from strongly agree (4) to disagree (1).

5 Data Analysis

The data were analysed using the Statistical Package for Social Science (SPSS) 23.0. The data analysis was divided into descriptive and inferential statistical analysis. Descriptive statistical analysis was used to overview the achievement and enjoyment mean scores. The mean and standard deviation values were used to address research questions related to achievement and enjoyment while learning the polygon topic among Form Two students. The inferential statistical analysis used in this study was an Analysis of Covariance (ANCOVA). ANCOVA was utilized to examine the contrast in achievement and enjoyment between the treatment and control groups, taking into account the pre-test scores as a covariate. Finally, we used the Pearson correlation to examine the relationship between student enjoyment and achievement for the polygon topic among Form 2 students.

6 Research Findings

6.1 Achievement on the polygon topic

This first research question aims to determine the level of achievement for the polygon topic among Form 2 students based on the scores obtained by the students on the Polygon topic achievement test. The results of this study show that the mean value of the experiment group (Mean= 35.50, SD= 10.40) was higher compared to the control group (Mean= 34.73, SD= 9.00) in the pre-test. Moreover, students exposed to teaching using GeoGebra software obtained better achievement on the Polygon topic than those exposed to traditional teaching. The mean value of the experiment group (Mean= 82.00, SD= 7.90) was higher compared to the control group (Mean= 52.00, SD= 5.50) in the post-test. Table 1 Level indicates the level of achievement for the polygon topic among second-form students.

Table 1: Level of achievement for the Polygon topic.

Group	**Pre test**		**Post Test**	
	Mean	**SD**	**Mean**	**SD**
Control	34.73	9.00	52.00	5.50
Experiment	35.50	10.40	82.00	7.90

SD = Standard Deviation

6.2 Enjoyment of the polygon topic

The second research question aims to determine the level of enjoyment of the Polygon topic among Form 2 students based on the scores obtained by the students in the mathematics enjoyment questionnaire. The value of the mean score of enjoyment as a whole and according to each sub-construct obtained is shown in Table 2. Overall, the findings show that the level of enjoyment among second-grade students was moderately high. Moreover, it was found that the constructs of enhancement (Mean = 2.603, SD = .748) were at the highest level, while enjoyment was at the lowest level (Mean = 2.547, SD = .850). At the same time, the mean value of involvement was (Mean= 2.580, SD= .360).

Table 2: The level of enjoyment for the Polygon topic.

Construct	**Sub-construct**	**Mean Score**	**Standard Deviation (SD)**
Enjoyment	Enjoyment	2.547	.850
	Enhancement	2.603	.748
	Involvement	2.580	.360
	Overall Mean	2.577	.652

6.3 The difference in achievement on the Polygon topic

This third research question aims to determine the difference in student achievement levels in the treatment and control groups for polygon topics. The null hypothesis, no significant difference in mean achievement score improvement between the treatment group and the control group, was performed. The Kolmogorov-Smirnov analysis for the achievement test showed non-significant values for the control group, for the control group sig. $= .74 (p > .05)$. This means that the achievement test for the control group was normally distributed. However, the table shows a significant value for the achievement test for the treatment group $= .000 (p < .05)$. This means that the achievement test for the treatment group was not normally distributed. Although the treatment group showed a significant Kolmogorov-Smirnov value (less than $.05$), the Skewness (-1.905) and Kurtosis (3.952) were in the acceptable range and showed good normality. According to Mayers [29], skewness and kurtosis values in the range of ± 1.96 indicate that the data was normally distributed. These findings indicated that the assumption of normality was upheld and not violated. At the same time, Levene's test yielded an $F = .889$ with a significance level of $0.073 (p > .05)$, indicating that the data displayed comparable variances across the groups. Therefore, ANCOVA can be employed to assess the disparity in the Polygon achievement scores between the treatment and control groups. Table 3 displays the possibility of conducting an ANCOVA to detect discrepancies in the Polygon achievement between the treatment and control groups.

Table 3: Difference in the Polygon achievement score of treatment and control groups.

Source	**Type III Sum of Squares**	*df*	**Mean Square**	*F*	**Sig.**	**Partial Eta Squared**
Corrected Model	13916.795[a]	2	6958.398	150.488	.000	.841
Intercept	4261.022	1	4261.022	92.152	.000	.618
Pre-test	39.191	1	39.191	.848	.361	.015
Group	13877.604	1	13877.604	300.128	.000	.840
Error	2635.617	57	46.239			
Total	287301.250	60				
Corrected Total	16552.413	59				

a. R Squared = .801 (Adjusted R Squared = .794)

The outcomes of the enjoyment presented in Table 3 revealed a statistically significant distinction in the achievement between the treatment and control groups $[F = 300.128$, sig $= .000\ (p < .05)]$. Specifically, students in the treatment group exhibited higher mean scores (Mean$= 82.00$) compared to students in the control group (Mean $= 52.00$). These findings indicate that the use of GeoGebra software was more effective than the traditional method in enhancing Polygon achievement. The magnitude of this differential effect was large, as indicated by Cohen's $d = .79$ [15]. This indicates that the null hypothesis (H_1^0) of no significant difference in the Polygon achievement between the treatment and control groups was rejected. The Polygon achievement possessed by the treatment group and the control group was different. The results of this test show that students exposed to teaching using GeoGebra software obtained better in Polygon achievement than those exposed to traditional teaching.

6.4 The difference in enjoyment on the polygon topic

The Kolmogorov-Smirnov analysis of student enjoyment showed non-significant values for the control group, for the control group sig. $= .200\ (p > .05)$. This means that the enjoyment test for the control group was normally distributed. However, the table shows a significant value for the treatment group sig enjoyment test $= .002\ (p < .05)$. This means that the enjoyment test for the treatment group was not normally distributed. However, the treatment group showed significant Kolmogorov-Smirnov value (less than $.05$), Skewness ($-.705$) and Kurtosis ($-.240$). This indicates that the enjoyment test for the treatment group was still normally distributed. Therefore, ANCOVA can be employed to assess the disparity in the enjoyment between the treatment and control groups. Table 4 displays the possibility of conducting an ANCOVA to detect discrepancies in the enjoyment between the treatment and control groups.

Table 4: Difference in the enjoyment score of treatment and control groups.

Source	**Type III Sum of Squares**	*df*	**Mean Square**	*F*	**Sig.**	**Partial Eta Squared**
Corrected Model	10.185[a]	2	5.093	114.584	.000	.801
Intercept	3.898	1	3.898	87.697	.000	.606
Pre-test	.208	1	.208	4.684	.035	.076
Group	9.722	1	9.722	219.877	.000	.794
Error	2.533	57	.044			
Total	411.071	60				
Corrected Total	12.78	59				

a. R Squared = .801 (Adjusted R Squared = .794)

The outcomes of the enjoyment presented in Table 4 revealed a statistically significant distinction in the enjoyment between the treatment and control groups $[F = 9.772$, sig $= .000\ (p < .05)]$. Specifically, students in the treatment group exhibited higher mean scores (Mean $= 3.006$) compared to students in the control group (Mean $= 2.148$). These findings indicate that the use of GeoGebra software was more effective than the traditional method in enhancing enjoyment. The magnitude of this differential effect was moderate, as indicated by Cohen's $d = .79$ [15]. This indicates that the null hypothesis (H_2^0) of no significant difference in the enjoyment between the treatment and control groups was rejected. The enjoyment possessed by the treatment group and the control group was different. The results of this test show that students exposed to teaching using GeoGebra software obtained better enjoyment of the Polygon topic than those exposed to traditional teaching.

6.5 Relationship between enjoyment and the achievement

The study hypothesis used in this study indicated that there was no significant relationship in the level of enjoyment between achievement on the post-test on the topic of Polygon among Form 2 students. The Pearson correlation demonstrates a significant correlation between enjoyment and achievement among form 2 students, with $r = .796$ and sig. $= .000\ (p < 0.05)$. The data analysis demonstrated a low association between enjoyment and achievement, with a positive correlation. The positive correlation does not support the null hypothesis (H_3^0) that no significant correlation exists between enjoyment and achievement among the Form 2 students. Students' enjoyment significantly affects achievement among Form 2 students.

7 Discussion

The main objective of this study is to investigate how the use of GeoGebra software affects both achievement and enjoyment among students. By focusing on the polygon topic, this study contributes to the existing literature by exploring the impact of GeoGebra software on student achievement and enjoyment in this area. The results revealed a high level of achievement on the Polygon topic among Form Two students. While both groups demonstrated high achievement scores, utilizing GeoGebra software significantly enhanced students' performance in this topic. These findings are aligned with previous research that suggests GeoGebra can effectively improve student achievement in geometry topics [31]. One of the key reasons behind this improvement is the software's visualization capabilities [7]. GeoGebra software enables students to create, manipulate, and explore polygons visually and interactively. By constructing polygons of various shapes, sizes, and orientations, students can readily observe the consequences of their actions, which aids in developing a clear mental image of polygons and enhances their understanding of their properties, relationships, and transformations.

Furthermore, the study also revealed high enjoyment of the polygon topic among Form Two students. Another study by Tamam and Dasari [36] supports these findings, indicating that GeoGebra software contributes to students' happiness. The data collected demonstrates that students who engage with GeoGebra software experience increased enjoyment in learning activities related to the Polygon topic. GeoGebra software promotes collaborative learning by facilitating project work and enabling students to share their work with peers and teachers. Through collaboration in constructing models, problem-solving, and discussions on mathematical concepts within the software, students are encouraged to communicate, work in teams, and exchange ideas. This collaborative learning environment enhances student engagement and facilitates a deeper comprehension of the subject matter.

The post-test results reveal a significant difference in achievement levels between the control and treatment groups on the Polygon topic among Form 2 students. Students exposed to GeoGebra software-based teaching achieved higher scores on the Polygon topic than those who received traditional teaching methods. This finding is consistent with previous studies conducted by Zulnaidi et al.[40]. These studies also support the notion that GeoGebra software enhances achievement by offering practical, easily comprehensible, and engaging lessons that improve students' visualization skills instead of mere memorization of theorems. One possible explanation for this improvement is that GeoGebra software allows students to interact visually with mathematical concepts, thereby deepening their conceptual understanding. Students can observe the relationships between various mathematical objects through dynamic representations and visualize abstract ideas. This visual approach facilitates the development of a strong foundation in mathematical concepts, ultimately leading to improved achievement in the subject. GeoGebra software empowers teachers to provide personalized instruction tailored to individual student needs. The software offers customizable options, interactive tools, and varying difficulty levels, enabling teachers to adapt the learning experience to match each student's abilities. By addressing different learning styles and providing tailored instruction, GeoGebra software supports improved achievement among students with diverse needs.

We discovered a significant disparity in enjoyment levels between the control and treatment groups on the post-test for polygon topics among Form Two students. The test results indicate that students exposed to GeoGebra software-based teaching experienced higher levels of enjoyment on the Polygon topic than those exposed to traditional teaching methods. The students in the treatment group expressed happiness when using the GeoGebra software, unlike the control group, who relied solely on traditional methods throughout the teaching and learning process. These findings are aligned with previous studies conducted by Topuz and Birgin [37], which suggest that incorporating technology in learning enhances students' enjoyment and view. Students tend to feel happier, more interested, and more focused on the subject matter being taught. One possible rationale for this observation is that GeoGebra software provides a dynamic and interactive platform that allows students to explore mathematical concepts through visualizations and manipulations. This interactivity promotes students' active engagement in the learning process.

They can experiment with different parameters, modify variables, and observe immediate changes in graphs, shapes, and equations. Other studies also support that using GeoGebra software encourages increased student interaction [33]. Students are more likely to experience heightened enjoyment when technology such as GeoGebra software is incorporated into their learning experiences. GeoGebra software provides an engaging and interactive learning environment that facilitates active participation, visualization, exploration, collaboration, and real-world connections. These features contribute to enhancing students' enjoyment of mathematics in the classroom.

Our study revealed a significant association between the experience of enjoyment and the academic performance of second-year students. These findings are consistent with prior research conducted by Sukor et al. [34]. One potential explanation is an increase in motivation. Enjoyment of mathematics can boost students' motivation to learn and excel in the subject. When students derive joy and satisfaction from solving math problems, they are more inclined to actively engage, invest effort, and persevere in their mathematical pursuits. This internal motivation drives them to dedicate themselves, concentrate, and willingly tackle challenging concepts. Simultaneously, enjoyment fosters active engagement in the teaching and learning process. Students who find math enjoyable are more likely to actively participate in classroom discussions, pose questions, and seek further comprehension. They may also exhibit heightened curiosity and a willingness to explore diverse problem-solving strategies, resulting in a deeper understanding of mathematical concepts and principles. Such active engagement facilitates meaningful learning experiences and contributes to improved academic achievement. According to Adelson and McCoach [1], mathematical enjoyment is defined as the extent to which an individual derives pleasure from learning mathematics.

8 Conclusion, Limitation and Future Work

Numerous studies have confirmed the impact of technology on mathematics education, and one software increasingly being utilized by teachers and educators is the GeoGebra software. Prior research has shown that the software can benefit students in the teaching and learning process, particularly in academic performance. This study adds to the existing literature by examining the effects of the GeoGebra software on student achievement and engagement, specifically on the Polygon topic. The study revealed that the level of achievement and engagement among Form Two students on the Polygon topic was already high. However, the findings demonstrated that students exposed to teaching using the software achieved even higher achievement and engagement than those who received traditional teaching methods. GeoGebra software's interactive and visual features significantly facilitated a deeper understanding of polygon properties, relationships, and transformations. Students were actively involved in exploring and manipulating the polygon topic, enabling them to visualize the characteristics of polygons and establish connections between various elements. The personalized and dynamic learning experience offered by the GeoGebra software also increased motivation, improved problem-solving skills, and enhanced conceptual understanding among students. Consequently, integrating GeoGebra software into the classroom proved valuable for enhancing student achievement and engagement on the polygon topic among Form Two students.

The current study possesses certain limitations that can be addressed in future investigations. These limitations encompass aspects such as sample size and representativeness, which may impact the generalizability of the findings. Enhancing the validity and applicability of the results can be achieved by including a more extensive and diverse sample of secondary school students. Employing randomized controlled trials with a larger sample size and random assignment to treatment and control groups would enable a more rigorous examination of the effects of the software on student achievement and engagement. Another limitation pertains to the need for a proper control group, making it challenging to isolate the specific effects of GeoGebra software on student achievement and engagement. The study may not have adequately accounted for other external factors that could influence student performance and involvement. Variables such as individual student characteristics, prior knowledge, teaching quality, or school environment could confound the results. The study might have solely assessed the short-term impact of the GeoGebra software on student achievement and engagement. Conducting longer-term follow-up assessments is valuable to ascertain whether the effects persist over time. Future research could incorporate various assessment tools and measures to capture different facets of student achievement and engagement. This could encompass standardized tests, surveys, classroom observations, and qualitative interviews to provide a more comprehensive understanding of the topic. Conducting longitudinal studies that track student progress over an extended period would offer deeper insights into the long-term effects of the GeoGebra software on achievement and engagement. Moreover, incorporating teacher perspectives and experiences in future research would provide valuable insights into the challenges associated with implementing the software effectively, the instructional strategies employed, and the professional development needs required.

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