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Mathematical Software: A Panacea for Improving Senior Secondary School Students' Retention in Geometrical Constructions

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ABSTRACT
When attempting to address the persistently poor performance of students in mathematics, researchers have typically examined factors such as retention to identify long-term solutions. The objective of this study was to improve the retention of senior secondary school students in geometrical constructions through mathematical software. Despite the many benefits of geometry to both the learner and society, the performance of the students continued to be abysmal. Could it be that the students do not retain what they learn? The research was conducted in Benue State, Nigeria, and was based on John Sweller's cognitive load theory of multimedia. The study's design utilised a non-randomised, quasi-experimental control group with a sample size of 457 students. Three objectives, research questions and research hypotheses led the study, with the Geometrical Construction Achievement Test and the Geometrical Construction Retention Test as the instruments for data collection. The mean and standard deviation of descriptive statistics were used to analyse the data that was gathered. The research reveals that retention was higher in the experimental group (Mean = 65.88) than in the control group (Mean = 51.87). The study found a statistically significant improvement in retention ($p < 0.05$). No gender variations were found when the students were taught with mathematical software. Mathematics teachers' utilisation of mathematical software as a strategy for teaching geometrical constructions among senior secondary school students was recommended.

KEYWORDS
Geometry; GeoEnZo; retention; gender; mathematical software.

INTRODUCTION

In trying to find long-term remedies for the appalling performance of learners in mathematics, variables such as retention are usually considered because students will perform better if they can retain what they have learnt. Thus, strategies that improve retention among students are now the concern of researchers, as suggested by the West African Examination Council's (WAEC) chief examiner's report (2022). One of the variables that contribute to learners' inadequate arithmetic proficiency is retention; hence, its improvement should be the concern of contemporary mathematics teachers. Valderama and Oligbo (2021) define retention as the ability to retain information in the mind, in both long- and short-term memory. Lutz and Huitt (2018) state that retention is when the learners process information cognitively, which includes comprehending, analysing, and storing it in memory. Ahlam and Gaber (2014) further defined retention as the recall of the learning and experience-related aftereffects that enable recognition. Ogbonna (2007), Kent and Sandra (2010), and Bennett et al. (2011) view retention as the ability to remember things and the capacity for recognition and recall (memory). Hornby in Amo (2017) defines retention as "holding onto," "holding onto or continuing to have," or "keeping in place.". The act of holding anything back is called retention, could be interpreted as "to continue having or holding" or as "absorbing and holding.". When students recall whatever they are taught, they tend to perform better. Amo (2017) states that in mathematics, students with strong retention skills outperform those with weak retention skills. Students' incapacity to remember what they have learnt contributes greatly to their poor achievement in geometry. The ability of students to remember what they have learnt is referred to as retention.

In this study, retention is viewed as the process of taking in, holding, or keeping mathematical facts under the geometrical construction concept taught. When students' achievement in any concept taught is not immediately measured, students' success is greatly dependent on what the students are able to retain. Mathematics teachers who are resourceful in their approach to teaching must concentrate on strategies that pique students' enthusiasm, attention, and retention rate while also acknowledging the individual variances among their students (Kurumeh et al.., 2012).

Retention in mathematics is one area that needs special attention in order to maximize the growth of students' total performance, just as achievement does. (Egbunu et al., 2017). Students retain what they learn well when lessons are accurately and meaningfully connected to their experiences and practical examples (Clarke & Roche, 2018). The use of appropriate instructional strategies is a step towards averting the menace of poor retention among senior secondary school students. Osemwinyen (2009) and Prabakaran and Saravanakumar (2020) find that the retention of students can be enhanced by utilising suitable teaching tools, such as mathematical software. According to their earlier research, Wang et al. Liu (2011), Karacop and Doymus (2013), and Bennett et al. (2011), students taught by computer animation retained information more effectively than those taught through any other technique. The learners' capacity to remember what they have learnt greatly depends on the strategy used to impact their knowledge.

Implementing a suitable method can increase students' engagement, leading to improved academic performance and ultimately enhancing students' ability to retain information. All facets of mathematics are covered using mathematical software, which has several benefits for high school mathematics teachers. McCulloch et al. (2018) believe that the usage of mathematical software in mathematics instruction can significantly improve mathematical instruction and student learning. Real-world problem-solving is one of the abilities and methods that are very relevant in the fields of science and mathematics topic area and can be supported by the usage of mathematical software (Greefrath et al., 2018; Huppert et al., 2002). Mathematical software is particularly helpful in applying mathematical knowledge and in understanding how mathematical knowledge can be imparted to students. It is also helpful in the development of relevant mathematical concepts by mathematics teachers. One of the programs that can be used to support students' retention is GeoEnZo., which was used for this study, and the detail is presented in the next section.

GeoEnZo is a computer program that makes it possible for the user to use a digital board in their mathematics class as a regular tool. (Age et al., 2021). With GeoEnZo, the users' outdated blackboard, whiteboard, board compass, and triangle grow outdated because it offers all the resources needed for geometry instruction and study. Mauladaniyati and Kurniawan (2018) state that GeoEnZo is one of the computer software programs that can be used as a medium in learning mathematics in the classroom. A window application called GeoEnZo provides the capabilities of instruction languages in English, French, Spanish, German, and Dutch (Sattar et al., 2015).

Figure 1.

Control Panel of GeoEnZo software   SourceGeoEnZo3.7©2009-2011ACJ

GeoEnzo is a technology-based strategy used for effective teaching of mathematics (Age & Machaba, 2023). Therefore, the study aims to determine whether GeoEnzo can enhance students' long-term retention of learned material and address the gender disparity identified by researchers.

The disparity in gender and achievement has a lot to do with what the students retain in a specified period. Owodunmi and Ogundola (2013) explain that the term gender is a sociocultural structure that results from a person's biological expectations based on their sex. Gender is used to describe particular cultural and behavioural tendencies that are linked to human males and females. Amo (2017) asserts that the disparity in gender roles does leave mathematics education unaffected; thus, the gender factor has been of great concern to mathematics educators and, hence, the present research. Given that each student is unique and may find different aspects of the instructional settings appealing, it is expected that they will find common ground for both learning and retention of the material (Owodunni & Ogundola, 2013).

Tsebo and Kurumeh (2014) found that male students attained and retained mathematics content significantly better than females. Okechukwu and Oyekunle (2018) found that students who were female did better than those who were male in their retention ability in mathematics even when exposed to the same teaching strategy. Relatedly, Ayuba (2017) showed that the retention rates of male and female pupils did not differ noticeably in algebraic word problems when exposed to computer-based instruction. Egbunu et al. (2017) and Age and Machaba (2023) suggest that providing equal opportunities for learning through engaging mediums like mathematical software is one method to close the gender gap in mathematics. Due to the inconclusiveness of gender and retention, the goal of this study is to ascertain whether using mathematical software is a beneficial strategy and a solution to the controversy mentioned above.

THEORETICAL FRAMEWORK

Cognitive Load Theory of Multimedia by John Sweller (1988)

According to Sweller (1988), the human brain has a finite capacity to process fresh information at a given time, while its ability to process stored information at a given time appears to be unbounded. According to Sweller, there are three categories of cognitive load: "extraneous cognitive load, intrinsic cognitive load, and germane cognitive load" (p. 259). The theory pertains to our investigation because when geometric constructs are taught, only the information that is relevant to the topics (intrinsic load) should be considered. The teacher, as well as the learner, should avoid the use of irrelevant information (extraneous load), which will lead to the overloading of the working memory, thus resulting in a lack of interest, low retention and low achievement among pupils in senior high school. This theory is relevant in the use of mathematical software as a strategy for teaching geometry since GeoEnZo is employed in the instruction and learning of many other mathematical concepts apart from geometry. It will be unnecessary for the teacher to start teaching the students the use of the software in other areas of mathematics apart from the concept of geometry at a given period, which will increase the extraneous load on the students' memory.

Attention should be basically given to the concept in question instead of trying to use the software in the learning of various mathematical concepts at a time, knowing fully well that there is a limit to which the student's memory can process information in each period. Moreover, if the student's memory becomes overwhelmed with unnecessary information, it will impede the processing of important concepts, ultimately impacting the student's ability to retain information. For example, if the concern of the teacher or the learner is to teach or learn geometry using GeoEnZo and proper concentration is given to the concept, one should only focus on the tools necessary for teaching and mastering geometry. This focus will enable the students to concentrate on the needed information (intrinsic load). Hence, the unnecessary information (extraneous load) will be reduced, thus promoting the germane load, which is responsible for the processing, construction, and automation of schemas. Retention is enhanced when a proper teaching or learning strategy is used, and the extraneous load is minimised to increase working memory capacity. Learners retain better when only relevant information (intrinsic load) on a given mathematical concept is learnt or taught.

Objectives of the Study

The objective of the research was to ascertain the mathematics software's efficiency at retaining geometrical concepts among senior secondary students. The study specifically aimed to determine:

i. Whether the utilization of the mathematics package for teaching improves the retention of geometry in High school students.
ii. Whether utilising mathematical software for teaching closed gender gap in students' retention of geometrical construction concepts
iii. The interaction of GeoEnZo and gender.

Research Questions

The study posed the following research questions:

i. What are the mean retention scores (RS) of learners in the study?
ii. What are the mean RS of the gender in the study?
iii. What is the interaction of GeoEnzo on gender as measured by the Geometrical Construction Retention Test (GCRT)?

Research Hypotheses

The following null hypotheses were tested at a significance level of 0.05.

i. There is no significant difference between the mean retention scores (RS) of learners in the study.
ii. There is no significant difference between the mean RS of the gender in the study
iii. There is no significant interaction of GeoEnzo on gender as measured by the Geometrical Construction Retention Test (GCRT).

METHODOLOGY

A quasi-experimental study of a non-randomised control group was used as the design for the study. Benue State, Nigeria, was the study area. The West African Examination Council chief examiner's report of 2016–2017 said that senior secondary school students in the state had poor retention in geometry, which contributed to their poor performance. This led to the selection of the area of the study.

The study's population consisted of all 12,308 students from 308 Government-approved Schools in the study area. The SS1 students were chosen as participants because, The Senior Secondary School Mathematics Curriculum states that students are first introduced to the idea of geometrical construction at this grade level. Out of the 12,308 SS1 students in total, 457 individuals were sampled as the study's respondents from four secondary schools. Two sampling techniques were used for this study: purposive and simple random techniques). Both simple random sample methods and purposive sampling were employed in this investigation. The researchers employed purposive sampling approaches to choose schools that satisfied the specified criteria: (i) Officially sanctioned by the government, (ii) presence of a fully operational computer laboratory, (iii) proficiency of students in computer operation, (iv) coeducational institution (enrolling both male and female students). Four schools were chosen using a simple random technique. two each for both experimental and control groups. The sample included 215 students for the control group (male = 113 and female =102) and 242 students for the experimental group (male = 112 and female = 130).

Data collection instruments included the Geometrical Constructions Achievement Test (GCAT) and the GCRT. A pilot test was done in a school located outside the student area. The collected scores were analysed, by utilizing Cronbach Alpha, a reliability coefficient of 0.96 was attained when test items were graded dichotomously as either right or wrong. Therefore, this approach can be utilised.

The validity of the instruments used for the research was confirmed by two secondary school mathematics instructors, two mathematics education specialists from Joseph Sarwuan Tarka University in Makurdi, Nigeria, and one expert in measurement and assessment.

The researcher briefed the regular SS1 mathematics instructors in the selected schools and enlisted them as research assistants. The lesson plans designed by the researcher were used to train the research assistants for the experimental group on how to use mathematical software (GeoEnzo) to teach and learn geometry. They were also provided with a user guide for the GeoEnzo. The experimental group's assistants to researcher were informed of the objectives of the research and the software installed on the computer used for the experiment. The prepared lesson plans for teaching geometrical constructions were also explained to the research assistants in the control group. The class met for forty minutes each day for a total of 240 minutes for six days. Below are examples of the activities conducted in both the control and experimental groups:

Classroom Activity for Control Group

Example 1: The teacher instructs the students on how to create a 90˚ angle.

The following steps illustrate the process of constructing a 90˚ angle as demonstrated by the teacher:

Step1: Create a straight line by connecting point B to point C, resulting in the line $\overline{\mathrm{BC}}$.

Step 2: Make B a centre, and draw a semi-circle with a convenient radius, intersecting the horizontal and vertical axes at coordinates x and y.

Step 3: Using the same radius as in Step 2 but with coordinates x and y as the centres, respectively, draw arcs to intersect the same circle at two different points, i.e. x^1 and y^1.

Step 4: With points x^1 and y^1, respectively, draw arcs to meet at a point A.

Step 5: Draw a line to join the line $\overline{AB}$. The needed angle is the angle obtained using the above steps (90^0).

The students adhere to the procedures as the instructor has previously demonstrated and construct an angle of 90^0.

Classroom Activity for Experimental Group

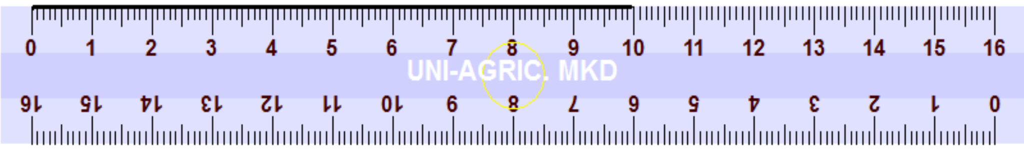
Example 1: The teacher teaches the students how to construct an angle of 90˚

The teacher constructs an angle of 90°, as shown below.

- Draw the arm AZ.

Figure 2.

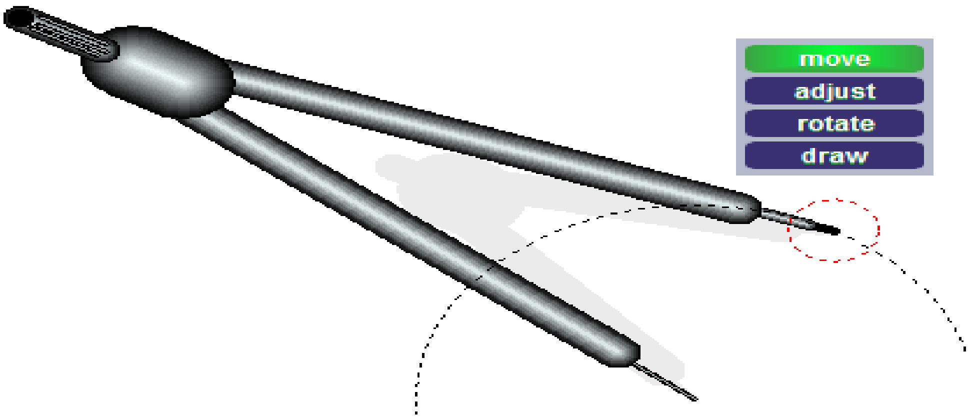
A ruler from the GeoEnZo software



- Position the compass at point A and draw an arc that intersects the line at B.
- Position the pointer of the compass at point B, then draw an arc with radius AB to intersect the arc previously drawn at C.

Figure 3.

A pair of compasses

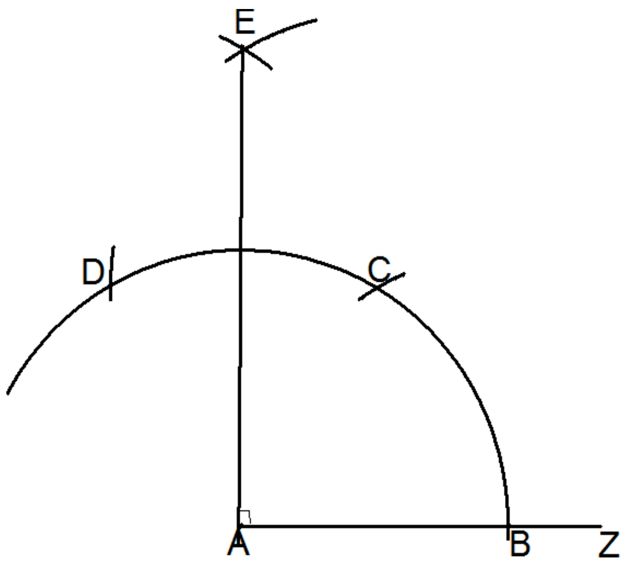


- Positioning the pointer of the compass at C, make an arc with a radius AB to intersect the previously created arc at D.
- While keeping the point of the compass at C, swivel the compass to create another arc of radius AB near point E.
- Moving the compass to D, create an arc of radius AB to intersect the arc drawn at E.
- Join A to E, the angle ZAE is 90˚

From the example mentioned, it is evident that the teacher in the control group engaged in explaining the systematic process of constructing the supplied angle, and the students observed attentively while the teacher provided explanations.

Figure 4.

Constructed Angle 90˚

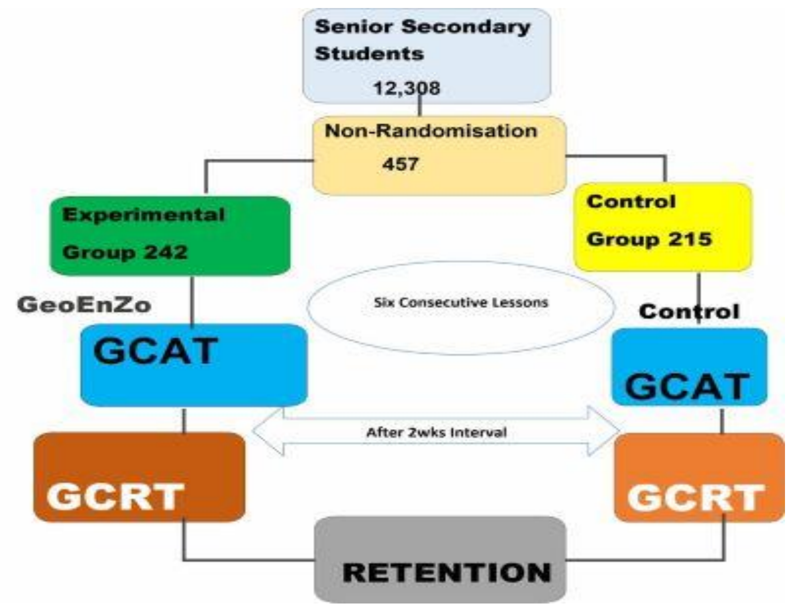


Meanwhile, in the experimental group, as the teacher explained, the steps explained by the mathematics teacher were followed up by the students in performing the construction on their computers.

The GCAT test was given to the groups (the experimental and control groups) simultaneously at the conclusion of the treatment period. To prevent interactions between the participants in both groups, the schools in these groups were spread out in different places.

Figure 5.

Methodology of the Study



Two weeks after the administration of the GCAT test, the items in the GAT were rearranged (that is, rearranging every item's serial number and the alphabetical symbols for the options) and administered to the subjects in both groups as in a Geometry Retention Test (GRT) to measure the retention of the subjects. According to Bahrick et al. (2008), From two weeks to several years, people were able to retain information for different lengths of time. The researcher analysed the collected data by utilising the descriptive statistics of the mean, standard deviation (SD) and scattergram answering the research questions. At the same time, the hypotheses were tested with ANCOVA (Analysis of Covariance) at 0.05 level of significance. The pre-test achievement scores and pre-interest ratings were used as covariates in the post-test, retention test and post-interest ratings.

RESULTS

The study's findings are outlined below in relation to the related hypotheses and research questions.

Research Question 1:

What are the mean retention scores (RS) of learners in the study? The answer to this research question is displayed in Table 1..

Table 1.

Means and Standard Deviations in the RS of Experimental and Control Groups

Groups		GAT		Retention-GRT	
	N	$(\bar{X})$	S. D	$(\bar{X})$	S. D
Experimental	242	68.94	12.03	65.88	11.26
Control	215	58.45	12.25	51.87	12.23
Mean Diff		**10.49**		**14.01**	
Total	**457**				

The experimental group's geometrical construction retention score is shown in Table 1 as 65.88, with an SD of 11.26, whereas the score for the control group was 51.87, with An SD of 12.23. In terms of geometrical construction retention, their mean retention difference is 14.01.

Research Hypothesis 1

There is no significant difference between the mean retention scores (RS) of learners in the study. The results of the hypothesis test are shown in Table 2.

The ANCOVA value is displayed in Table 2. $F(1, 454) = 100.628$, at a $p = .001 < 0.05$ level of significance. Therefore, the null hypothesis is disproved. It shows that there is a substantial difference between the mean RS of SS1 students taught geometrical constructs in the experimental and control groups. The outcome suggests that learning with mathematical software boosts students' retention of geometrical constructions more than the traditional method.

Table 2.

ANCOVA Results of learners' Retention scores.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	46580.231[a]	2	23290.115	276.032	.001	.549
Intercept	5524.806	1	5524.806	65.480	.001	.126
GAT	24247.072	1	24247.072	287.374	.001	.388
Group	**8490.404**	**1**	**8490.404**	**100.628**	**.001**	**.181**
Error	38306.062	454	84.375			
Total	1691436.000	457				
Corrected Total	84886.293	456				

a. R Squared = .549 (Adjusted R Squared = .547)

Research Question 2

What is the mean RS of gender in the study? Table 3 displays the answer to this query.

Table 3.

Means, SD, of and RS of gender in the study.

Groups		GAT		Retention-GRT	
	N	$(\bar{X})$	S. D	$(\bar{X})$	S D.
Male	112	67.04	11.42	68.66	10.39
Female	130	67.05	9.30	68.32	10.02
Mean Diff		**-0.01**		**-0.34**	
Total	242				

Table 3 reveals that the mean post-test geometrical construction value of 67.04 for male learners in the experimental group and 11.42 as the SD, whereas, the female had a mean post-test score of 67.05 with a SD of 9.30. Two weeks after the post-GAT, the male experimental group's mean RS value was 68.88 with an SD of 10.39 and 68.32 with an SD of 10.02.

Hypothesis 2

There is no significant difference between the mean RS of the gender in the study. The ANCOVA result for the hypothesis is displayed in Table 4.

Table 4 shows the ANCOVA value F (1, 239) = .564, at p = .453 > 0 .05 level of significance. Considering that the null hypothesis was not rejected, there is no discernible difference in the GRT-measured mean RS. of learners taught geometry with GeoEnZo.

Table 4.

ANCOVA Results of RS of Learners

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	21744.197[a]	2	10872.098	811.452	.001
Intercept	252.878	1	252.878	18.874	.001
Group	21737.338	1	21737.338	1622.392	.001
Gender	**7.554**	**1**	**7.554**	**.564**	**.453**
Error	3202.200	239	13.398		
Total	1159786.000	242			
Corrected Total	24946.397	241			

Research Question 3

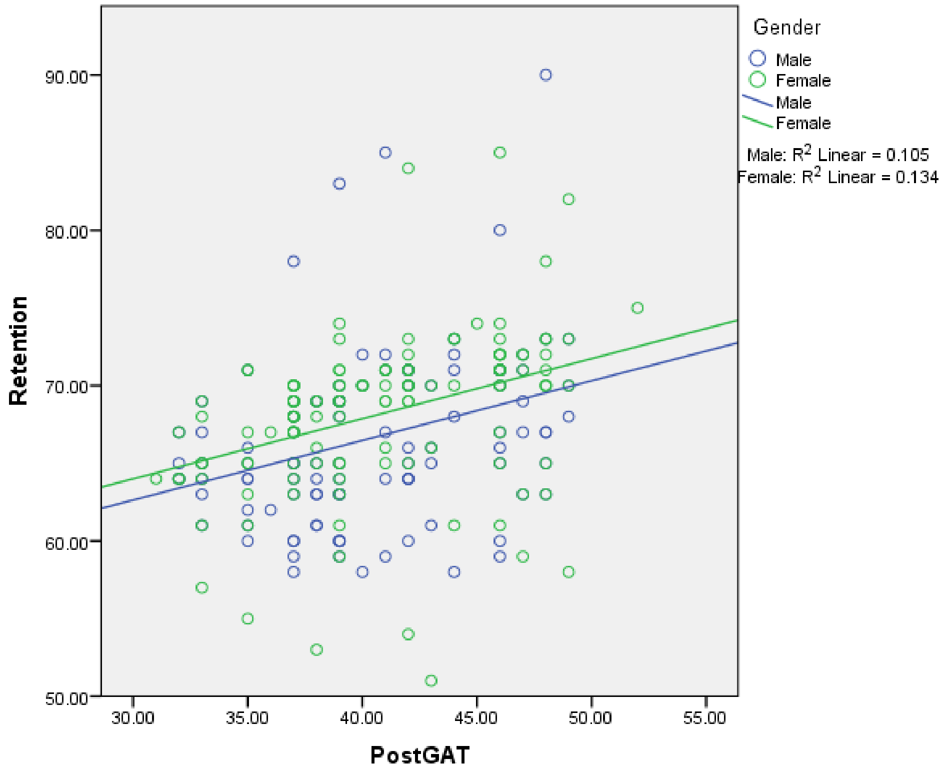
What is the interaction of GeoEnzo on gender as measured by the Geometrical Construction Retention Test (GCRT)? Figure 6 provides the response to this query.

Linearity Scattergram of

Figure 6.

Gender and GeoEnZo interaction

The outcome shown in Figure 6 shows that the two lines on the geometry retention test that



indicate the male and female gender variables are parallel. From the y-axis to the upper left of the x-axis, they both start. This suggests that there is no connection between gender and

GeoEnZo and the retention of geometrical constructions in SS1 students. Hence, this suggests that gender has no bearing on SS1 students' use of mathematical software to retain geometry.

Hypothesis 3

There is no significant interaction of GeoEnzo on gender as measured by the Geometrical Construction Retention Test (GCRT). Table 5 displays the ANCOVA result.

Table 5.

The Interaction between GEOENZO and Gender: Results of the ANCOVA

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	957.897[a]	3	319.299	12.788	.001	.139
Intercept	8572.329	1	8572.329	343.320	.001	.591
Gender	1.295	1	1.295	.052	.820	.001
Group	796.866	1	796.866	31.914	.001	.118
Gender * Group	**.014**	**1**	**.014**	**.001**	**.981**	**.000**
Error	5942.603	238	24.969			
Total	1109513.000	242				
Corrected Total	6900.500	241				

a. R Squared = .139 (Adjusted R Squared = .128)

The outcomes of Table 5, the F value (1, 238) = .005, P = 0.981, p > 0.05, Partial Eta Squared = 0.000. The computed interaction effect's percentage was 0.000 x 100 = 0.00. thus, no rejection of the null hypothesis occurs. Therefore, there is no substantial interaction of the mathematical software and gender on the retention of SS1 students in geometrical constructions. The gender component does not affect the retention of learners in geometrical construction.

DISCUSSION OF MAJOR FINDINGS

The efficiency of using computer programs for mathematics teaching in SS1 students' retention of geometrical construction was considered in this study. The results were discussed in the order they were presented.

The results of this investigation show a substantial difference between senior secondary learners who used GeoEnZo for geometry teaching and those who did not. Senior secondary students who received geometry instruction with GeoEnZo obtained higher retention mean scores than pupils who received geometry instruction in the traditional manner. The results support the findings of Obi et al. (2014), who studied the effect of Origami on students' retention in geometry, which showed that the retention of junior secondary school students was enhanced when Origami was used in teaching geometry. In agreement with the findings, Birgin and Yazici (2021) examined the impact of utilising dynamic geometry software (GeoGebra) on the conceptual comprehension and long-term retention of linear equations and slopes among eighth-grade students. The results revealed a considerable improvement in students' recollection of the learned material. Similarly, Gambari et al. (2014), Ogunkunle and Onwunedo (2014), Ozofor (2015) and Topuz (2017) had similar findings in the studies they conducted, which revealed that students retain more when exposed to instruction with the use of technology. On the other hand, Penaloza (2015) studied the effectiveness of retention software on retention and graduation rates and found that the outcome rate of the learners did not improve.

The findings of this study also show that there is no statistically notable variation between male and female students taught geometry using GeoEnZo's mean retention ratings, with the mean RS for both genders being equal. This outcome confirms the previous findings of Obi et al. (2014), who reported that there was no statistically notable gap between the retention rates of male and female students when using Origami. Ayuba (2017) in his study discovered no appreciable variation in retention between the genders instructed via CBI. Also, Amo (2017) found that the percentages of student retention for both male and female were not significantly different in his research. Similarly, Nkok (2021) and Olorukooba et al. (2016) found no significant difference in the retention of male or female students. The findings of this study contradict the findings of Egara and Mosimege (2023), who used a computer simulation to study the effect of gender difference on secondary school students' retention in algebra. They found that male students retain more than female students. However, with the use of mathematical software such as GeoEnZo, the gender gap in the retention of learners is closed.

The study's findings also reveal that the retention of SS1 students taught geometry using GeoEnZo is independent of gender. The outcome validates the previous discoveries by Age (2017), Age et al. (2021) and Age and Machaba (2023) in their studies that revealed no interaction on gender differences in the application of mathematical software on learners.

Recommendations

The researchers recommend that mathematics instructors should consistently employ mathematical software when teaching geometrical concepts to enhance their students' ability to remember geometrical constructions.

Similarly, to increase the retention rate of students, male and female, school administrators should establish a supportive environment that allows mathematics teachers to use mathematical software to help them when imparting geometric construction knowledge. Relatedly, the profession's pertinent players in mathematics education should organize conferences and seminars where this innovative, software-based instruction is presented. It might be suggested for efficient geometry instruction and learning in secondary schools to improve students' retention.

CONCLUSIONS

According to the study's findings, when senior secondary students were taught geometry using mathematical software, their retention rate increased. Additionally, the retention of students who were exposed to geometrical constructions via mathematical software improved more than it did for learners who did not receive instruction using mathematical software. However, as measured by GCRT, there is no interaction between the gender of senior secondary students and the mathematical software.

Limitations of the Study

The following were the limitations of the study:

i. Some of the computer systems in the selected schools were not functional, thus restricting most of the students' access to the computers and limiting their zeal to explore GeoEnZo.

ii. The study also faced the challenge of power outages, particularly in the experimental group, and while alternating the power source, time for the study would have been limited as intact classes were used.

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