UNIVERSIDAD & SOCIEDAD
Presentation date: January, 2025
Date of acceptance: May, 2025
Publication date: June, 2025

THE PERCEIVED

INFLUENCE OF GEOBOARD ON JUNIOR SECONDARY SCHOOL STUDENTS' PERFORMANCE IN GEOMETRY

LA INFLUENCIA PERCIBIDA DEL GEOBOARD EN EL RENDIMIENTO DE LOS ESTUDIANTES DE SECUNDARIA EN GEOMETRÍA

Age, Terungwa James[1*]
E-mail: agetj@unisa.ac.za
ORCID: https://orcid.org/0000-0001-7444-2213
Machaba, Masilo France[1]
E-mail: emachamf@unisa.ac.za
ORCID: https://orcid.org/0000-0003-1318-3777
[1]University of South Africa. South Africa.
*Corresponding author

Suggested citation (APA, seventh ed.)

Age, T. J. & Machaba, M.F. (2025). The Perceived Influence of Geoboard on Junior Secondary School Students' Performance in Geometry. ***Universidad y Sociedad, 17***(3). e5118.

ABSTRACT

Mathematical software and other technological tools are key ingredients in the teaching and learning of mathematical concepts such as geometry which has numerous benefits to the learner and the society because of its applications in our daily lives. Are the learners aware of the benefits of software such as Geoboard and whether its use improves their performance? Hence, there is a need to determine the perceived influence of Geoboard on Basic 8 (eighth-grade level primary education) students in Junior Secondary Schools in Nigeria in terms of the teaching and learning of geometry. Two research objectives and two questions were formulated with a survey research design. A sample of 236 Junior Secondary II students was drawn through a multi-stage sampling technique in Benue state, Nigeria. The instrument used for data collection was the Perceived Influence of Geoboard Questionnaire (PIGQ). The results indicate that the use of Geoboard influenced the performance of students in geometry, as is evident from the individual item mean rating and cluster mean (= 3.58). The result also revealed that there is no gender difference in the perceived influence of Geoboard on students' performance in geometry (= 2.95 for male and =2.96 for female). The study concluded that using Geoboard influenced junior secondary students' performance in geometry. Additionally, there was no gender difference in the perceived influence of Geoboard on male and female junior secondary school students in geometry.

Keywords: Geometry, Geoboard, Junior school students, Mathematical Software.

RESUMEN

El software matemático son elementos clave en la enseñanza y el aprendizaje de conceptos matemáticos como la geometría, que tiene numerosos beneficios para el alumno y la sociedad, debido a sus aplicaciones en la vida cotidiana. ¿Son conscientes los alumnos de las ventajas de programas informáticos como el Geoboard y de si su uso mejora su rendimiento? Por lo tanto, es necesario determinar la influencia percibida del Geoboard en los alumnos de 8º de Educación Básica (octavo grado de Educación Primaria) de los centros de Secundaria de Nigeria en lo que se refiere a la enseñanza y el aprendizaje de la geometría. Se formularon dos objetivos de investigación y dos preguntas con un diseño de investigación de encuesta. Se seleccionó una muestra de 236 alumnos de segundo ciclo de secundaria mediante una técnica de muestreo en varias etapas en el estado de Benue, Nigeria. El instrumento utilizado para la recogida de datos fue el Cuestionario de Influencia Percibida de los Geoboards (PIGQ por sus siglas en inglés). Los resultados indican que el uso del Geoboard influyó en el rendimiento de los estudiantes en geometría, como se desprende

This work is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License

de la calificación media de los ítems individuales y de la media del grupo ($\bar{x}$ = 3,58). El resultado también reveló que no hay diferencia de género en la influencia percibida de Geoboard en el rendimiento de los estudiantes en geometría ($\bar{x}$ = 2,95 para el sexo masculino y $\bar{x}$ =2,96 para el sexo femenino). El estudio concluyó que el uso de Geoboard influyó en el rendimiento de los estudiantes de primer ciclo de secundaria en geometría. Además, no hubo diferencias de género en la influencia percibida del Geoboard en los alumnos y alumnas de primer ciclo de secundaria en geometría.

Palabras clave: Geometría, Geoboard, Estudiantes de secundaria básica, Software matemático.

INTRODUCTION

Mathematical software and other technological tools are key ingredients in the teaching and learning of mathematical concepts such as geometry, which have numerous benefits for the learner and society because of their application in our daily lives. All aspects of our daily lives are touched by the applications of the mathematical idea of geometry (Age & Machaba, 2023; Tessema et al., 2024). Geometric forms and objects are present in our physical world; therefore, learning geometry is important not only for its significance in various professions but also because of its prevalence (Jablonski & Ludwig, 2023). Geometry is a discipline of mathematics that focuses on measurement and qualities of points, lines, curves, and surfaces. Similarly, Akpan et al. (2023) opine that the study of the nature, characteristics, measurements, and connections between points, lines, angles, and figures in space is known as geometry. Geometry gives rise to the development of mathematical thinking, encompassing both abstract reasoning and modelling and tangible depiction. Even though geometry is essential to many fields, research has shown that students find it challenging. This is likely due to various factors, including how geometry is taught, the students' lack of background knowledge, inability to visualize, and ignorance of proofs (Alghadari & Herman, 2018). This study focused on the strategy used in teaching and learning geometry; it x-rayed the perceived influence of GeoGebra on students' performance in geometry.

Applications of mathematical knowledge and comprehending the best ways to teach mathematics to students are made easier with the aid of mathematical software (Age & Machaba, 2024). Teachers of mathematics can also use it to develop pertinent mathematical topics. When teaching mathematics in secondary school, mathematical software can be a very useful tool. The program can make tough subjects come to life and exciting by using interactive models and captivating 2D/3D graphics to explain hard arithmetic ideas. Utilizing mathematical software will make learning more engaging, creative, and inquisitive (Age & Machaba, 2023; Kyabuntu & Mbhiza, 2024). Despite its inherent quirks, the use of mathematical software for teaching and learning mathematical concepts has long been seen as beneficial, which is evident in the studies conducted by researchers.

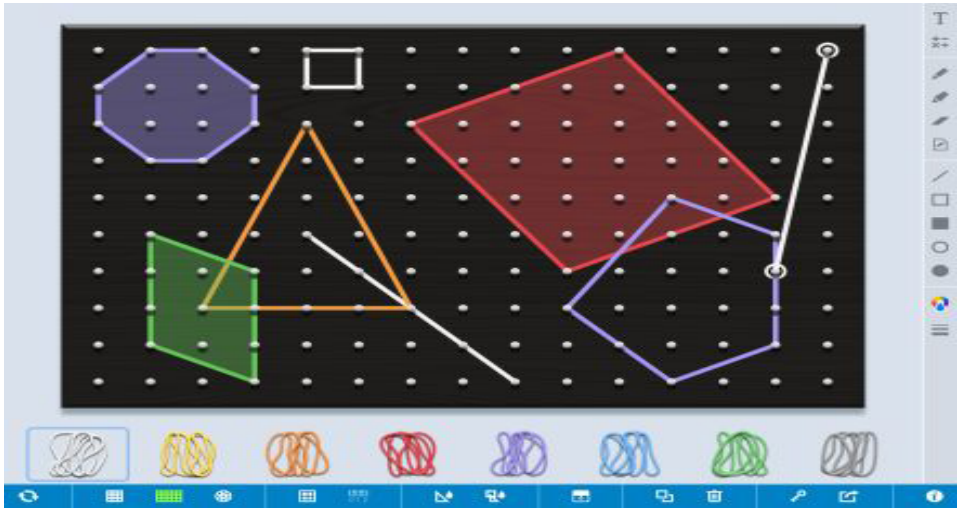
Age et al. (2021) investigated the effect of GeoEnzo on students' interest in geometry, and the results showed that the mathematical software used enhanced the students' interest in geometry and revealed no gender differences in the levels of interest in geometry concepts. Similarly, Ji et al. (2024) carried out a study on the impact of the Dynamic Mathematical Software (DMS) intervention on the improvement and achievements of school students and the variables that could affect their efficacy. Findings indicate that DMS improves student performance, and educators should take great care while creating lesson plans. Similarly, Mario et al. (2024) studied the effect of GeoGebra Software and playful strategies on mathematics learning in students of a state educational entity in Piura. The study's findings showed that using GeoGebra software and playful methods significantly impacts mathematics learning. Furthermore, Noverianto et al. (2024) researched "the influence of the GeoGebra-assisted discovery learning model on students' mathematical *problem-solving* abilities in geometry learning" (p. 331). The results of the study showed that students' problem-solving skills are improved by the GeoGebra-assisted Discovery Learning Model, making it applicable to the study of mathematics, particularly geometry, in junior and senior high. Since several researchers have employed and explored these and numerous other mathematical software programs, the emphasis of this study is Geoboard.

Geoboard is a mathematical tool for investigating fundamental ideas in plane geometry, including area, perimeter, and the properties of triangles and other polygons. It comprises a square board with a predetermined number of nails or pegs arranged in rows and columns. Rubber bands can be stretched to form different forms around the pegs or nails (Okoye & Onyeka, 2022). Geoboard is a teaching tool that helps students investigate a range of fundamental mathematical ideas, including geometry, measurement, graphing, and counting (Poloamina et al., 2024).

A geoboard is a flat board with a grid of nails or pegs organized in square or rectangular patterns, as shown in Figure 1. It is a mathematical manipulative instrument. Students can learn geometry, spatial reasoning, and

mathematics principles through a hands-on method by creating geometric shapes and patterns with rubber bands or strings wrapped around the pegs

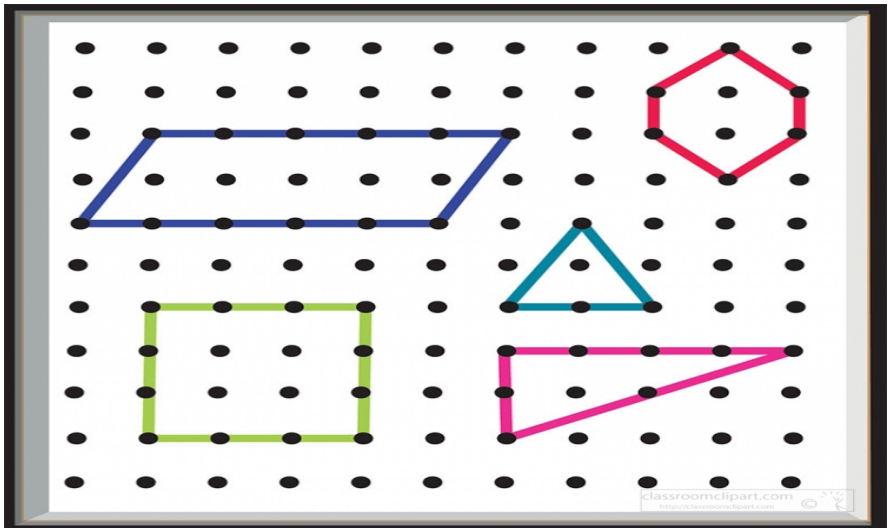
Fig 1: A Screen with a Geoboard Showing the Menu and Toolbars.



Source: own elaboration.

Geoboard is a mathematics manipulative that is used to instruct students in spatial reasoning and geometric ideas, as demonstrated in the ready-made shape geoboard in Figure 2. The use of Geoboard is beneficial to the students as it aids students in visualizing and comprehending ideas like symmetry, area, perimeter, and forms. It also improves students' hand-eye coordination, fine motor skills, problem-solving aptitude, and spatial awareness and comprehension of geometric forms. Geoboards are effective for raising students' mathematics performance and spatial visualization skills (Sibiya, 2020). Relatedly, students who utilize concrete (physical) geoboards learn geometry more effectively, as demonstrated by their improved proficiency in the subject. This is consistent with the claim that one of the steps to improve students' performance in geometry is using technology (Age & Machaba, 2023; Hengki et al., 2024). Hence, there is a need to study the perceived influence of Geoboard on students' geometry performance.

Fig 2: Geoboard with Ready-Made Shapes.



Source: own elaboration.

Statement of the Problem

Despite apparent improvements in applicants' mathematics performance, the West African Examination Council's (WAEC) Chief Examiner's report (WAEC, 2022) observes that students' performance in geometrical concepts is weaker than other concepts in mathematics. This poor performance in geometry affected students' overall mathematics performance. Of the 1,222,505 students who sat for WAEC in 2022, 76.36% passed, while 23.6% failed. As a result, the report recommends that teachers and students work harder to teach and learn geometry to improve students' overall performance. Similarly, Usman et al. (2020) declare that geometry is the worst- most poorly performing topic in mathematics in both internal and external examinations in Nigeria, which adds to the subject's general low performance. This abysmal performance can be attributed to the strategy used in teaching and learning geometry. Students who learn geometry via the conventional process are often unable to identify geometric figures, their properties, and the connections between the forms. While instructional strategies like teacher exposition have a place in mathematics education, teachers frequently prioritize topic memorization over meaning formation. Several research studies have shown how the use of mathematical software such as Geoboard has improved students' performance in geometry; hence, the need for this study to determine the perception of students on the use of Geoboard.

Purpose of the study

This study aimed to determine the perceived influence of Geoboard on students' performance in geometry. The study sought to determine whether the use of Geoboard

1. i. influenced the performance of students in geometry
2. ii. reduced the gap in male and female students' performance in geometry.

Research Questions

In this study, the following research questions were posed:

1. What are the ratings of the perceived influence of Geoboard on students' performance in geometry?
2. What are the ratings of the perceived influence of Geoboard on male and female students' performance in geometry?

This study was anchored on the Van Hiele theory of geometrical thinking of 1957. The model describes how young people learn geometry. It postulates five levels of geometric thinking: (i) Visualization, (ii) Analysis, (iii) Abstraction, (iv) Formal deduction, and (v) Rigor. Each level uses its own language and symbols. However, for this study, only the first three steps were used.

Table 1 shows the application of the theory in the learning of geometry at junior secondary school levels.

The first three levels of the geometrical thinking theory are applicable to the study since the respondents are Basic 8 students whose curriculum covers topics that develop visualization, descriptive and analytic thinking, and abstract/relational thinking. The theory is relevant to the study because learning geometry with Geoboard is done at different levels. Table 1 demonstrates how the learning moves from one level to another for learning geometry.

Table 1: Application of Van Hiele Theory in Learning Geometry.

LEVEL	DESCRIPTION	ACTIVITIES
One: Visualization	• Recognise and manipulate shapes and other geometrical configurations based on their appearance. • Perception dominates reasoning. • Visual recognition of objects is based on "the same shape".	• Have a discussion after making shapes on the geoboard. • Create as many variations of the same shape as possible using size and position on the geoboard. • Request that students adhere to instructions and then inquire as to what shape they have created.

Two: Descriptive/ Analytic	• Identifies and describes shapes according to their characteristics • View figures as wholes, but now as groups of characteristics instead of visual gestalts. • Experimental methods such as observation, measurement, drawing, and modeling are used to establish properties.	• Display many shapes on the geoboard and discuss their similarities and differences. • Ask pupils to use a certain property to create a shape, for example, four sides and talk about the similarities and distinctions in the shapes created.
Three: Abstract/ Relational	• Create abstract definitions. • Distinguish between sets of sufficient and essential requirements for a concept. • Argue based on the characteristics of figure classes. • Restructure concepts by connecting the characteristics of individual figures with their classes.	• Students should arrange the shapes on the Geoboard based on their attributes (let them choose the criteria). • Rotating and reflecting shapes. • Examining the symmetry of shapes with mirrors.

Source: own elaboration.

MATERIALS AND METHODS

This study used a survey research design with two schools in Makurdi, the capital of Benue state, Nigeria, as the research sites. The study used a multistage sampling technique. The study employed a multistage sampling technique since different sampling techniques were applied at different study phases. Purposive sampling techniques were used in selecting eight schools that have used Geoboard in teaching and learning geometry, while a simple random technique was used in sampling the two schools used for the study. A sample size of 236 students at the Basic 8 level was used. Within the sample, school A had 124 respondents (56 female, 68 male), and School B had 112 respondents (58 female, 54 male). The instrument used for data collection was the Perceived Influence of Geoboard Questionnaire (PIGQ), which was developed by the researcher. The instrument consists of 15 items scored on a four-point Likert rating scale with a decision benchmark of 2.50: Strongly Agreed (SA) = 4, Agreed (A) = 3, Disagree (D) = 2, and Strongly Disagree (SD) = 1. Two specialists in mathematics education and one expert in measurement and evaluation duly evaluated the instrument to ascertain its validity. The inputs of the validation process were integrated into the instrument, leading to the outcome of a valid questionnaire fit to be used for the study. A trial test was carried out on 20 students outside the study area, and the scores collated were analysed using Cronbach Alpha. A reliability coefficient of 0.86 was established; thus, the instrument was found to be reliable and fit to be used for the study. Two research assistants helped distribute and collect the questionnaires from the respondents. The data collected was analysed using descriptive statistics, evaluating the Mean and Standard Deviation in answering the research questions formulated for the study.

RESULTS AND DISCUSSION

The study's results are presented according to the research questions guiding the study. Research Question 1: What are the ratings of the perceived influence of Geoboard on students' performance in Geometry?

Table 2 depicts the students' responses to the relevant questionnaire. The results from the table show that all the items have a mean above the decision point of 2.5 and a cluster mean of 3.58, which implies that Geoboard influences the students' performance. This is demonstrated by the students' responses, which have high mean ratings ranging from 3.32 to 3.80.

Research Question 2: What are the ratings of the perceived influence of Geoboard on male and female students' performance in Geometry?

Table 2: Students' Perceptions of the Influence of Geoboard on Their Mathematics Performance.

S/NO.	ITEM	SD (1)	D (2)	A (3)	SA (4)	Mean ()	S. Dev	Dec.
1	My performance is enhanced when I use Geoboard to practically visualize a topic in Geometry.	8	14	110	104	3.61	0.53	A

2	Geoboard practically put the properties of geometric shapes before me and helps me perform better.	8	15	94	119	3.62	0.55	A
3	I perform better when I use Geoboard to do practical calculations.	10	14	99	113	3.32	1.08	A
4	My performance improves when I can measure the dimensions of geometric shapes on Geoboard.	10	15	91	120	3.51	0.55	A
5	With a protractor on the geoboard, I am able to measure some angles more accurately.	9	15	112	100	3.52	0.85	A
6	Dividing various shapes using Geoboard helps me perform better in geometry.	8	14	103	111	3.70	0.52	A
7	Using strings and pegs on the geoboard to construct shapes helps me do better in geometry.	9	14	85	126	3.63	0.54	A
8	The ability to create plane shapes with Geoboard helps me perform better in mensuration...	10	15	90	121	3.60	0.55	A
9	My performance improves as I examine and comprehend the various characteristics of geometrical shapes using Geoboard.	11	14	174	137	3.58	0.64	A
10	Using Geoboard to complete some geometric class assignments helps me perform equally with most of my classmates.	10	15	82	129	3.51	0.55	A
11	Even in situations where the teacher is not around, I always attempt to use Geoboard by myself.	12	13	94	117	3.56	0.75	A
12	I happily attend geometry classes now that I have a geoboard.	9	18	106	103	3.71	0.56	A
13	Geoboard's presence has caused me to pay closer attention in Geometry topics.	11	14	107	104	3.51	0.55	A
14	I do always complete my homework and in-class assignments easily because of Geoboard.	9	13	91	123	3.57	0.78	A
15	Geometric classes are interesting to me now that I have a geoboard.	11	12	122	91	3.80	0.41	A
						3.58		A

Source: own elaboration.

Table 3 depicts the students' responses to the relevant questionnaire. The table shows male and female students' responses about their perceptions of the influence of using Geoboard on their performance in geometry. The two genders have cluster means of 2.95 and 2.96, respectively, which is greater than the decision point of 2.5. This statistic implies that both genders perceived geoboard as influencing their performance in geometry. The difference between the cluster means of male and female students' perceptions was 0.01, which is statistically insignificant. Thus, male and female students do not have different perceptions.

Table 3: Male and Female Students' Perceptions of the Influence of Geoboard on Their Mathematics Performance.

S/N	ITEM	Strongly Disagree (1)		Disagree (2)		Agree (3)		Strongly Agree (4)		Mean ()		S. Dev.	Decision
		M	F	M	F	M	F	M	F	M	F		
1	My performance is enhanced when I use Geoboard to practically visualize a topic in Geometry.	7	5	7	3	61	45	49	59	2.80	2.88	0.76	NGD
2	Geoboard practically put the properties of geometric shapes before me and helps me perform better.	8	6	7	2	39	49	70	55	3.05	3.06	0.62	NGD
3	I perform better when I use Geoboard to do practical calculations.	6	5	8	5	45	53	65	49	2.85	2.87	0.72	NGD
4	My performance improves when I can measure the dimensions of geometric shapes on Geoboard.	9	7	6	3	52	45	60	54	3.01	3.03	0.72	NGD
5	With a protractor on the geoboard, I am able to measure some angles more accurately.	4	3	11	6	53	59	50	50	3.15	3.13	0.80	NGD
6	Dividing various shapes using Geoboard helps me perform better in geometry.	7	6	15	8	50	48	52	50	2.84	2.85	0.77	NGD
7	Using strings and pegs on the geoboard to construct shapes helps me do better in geometry.	7	5	7	3	42	40	70	62	2.86	2.88	0.76	NGD
8	The ability to create plane shapes with Geoboard helps me perform better in mensuration	8	6	7	2	34	66	65	46	3.15	3.17	0.84	NGD
9	My performance improves as I examine and comprehend the various characteristics of geometrical shapes using Geoboard.	6	5	8	5	20	50	80	62	2.84	2.85	0.75	NGD
10	Using Geoboard to complete some geometric class assignments helps me perform equally with most of my classmates.	9	7	6	3	31	61	68	51	2.85	2.81	0.77	NGD
11	Even in situations where the teacher isn't around, I always attempt to use Geoboard by myself.	4	3	11	6	47	52	60	53	3.30	3.33	0.74	NGD
12	I happily attend geometry classes now that I have a geoboard.	7	6	15	8	50	40	50	60	2.84	2.85	0.75	NGD

13	Geoboard's presence has caused me to pay closer attention in Geometry topics.	6	5	8	5	66	40	40	66	3.11	3.09	0.78	NGD
14	I do always complete my homework and in-class assignments easily because of Geoboard.	9	7	6	3	60	40	64	47	2.77	2.78	0.83	NGD
15	Geometric classes are interesting to me now that I have a geoboard.	4	3	11	6	71	38	29	74	2.84	2.85	0.76	NGD
	Cluster Mean									2.95	2.96		NGD

Note: NGD means No Gender Difference

Source: own elaboration.

DISCUSSION OF RESULTS

The study showed that the Basic 8 students perceived that using Geoboard influenced their performance in geometry. This finding is based on the fact that Basic 8 students who were taught geometry using Geoboard perceived that their performances improved as a result of learning geometrical concepts by using Geoboard. This finding agrees with Akpan et al. (2023) who found that the use of Geoboard in the teaching and learning of geometry improved students' performance in mathematical concepts, especially geometrical shapes. Relatedly, Age and Machaba (2023), Akpan et al. (2023) revealed in their studies that using mathematical software enhanced students' performance in geometry as the students examined and comprehended the various characteristics of geometrical shapes using Geoboard.

Furthermore, the study's findings revealed no difference in the perception of male and female students regarding the influence of a geoboard on their performances in geometry. The implication is that the use of geoboard influenced the performance of both male and female students equally, with no gender difference, hence closing the gender gap, as pointed out by various researchers. In support of this finding, Eriksson (2020) reported no gender difference in students' geometry performance when taught geometrical concepts with mathematical software. In contrast, Makondo and Makondo (2020) discovered that male and female students' performance differed in some areas of mathematics, particularly geometry. Relatedly, Akpan et al. (2023) found that in the mathematical concept of geometry, male students were found to perform much better than female students.

RECOMMENDATIONS

For the effective teaching and learning of geometrical concepts by junior secondary school students, the researchers recommend that mathematics teachers regularly use mathematical software like Geoboard to improve student performance.

Likewise, school administrators ought to foster a supportive environment, enabling mathematics teachers to utilize appropriate software to facilitate the instruction of geometric construction, thereby addressing the gender disparity in geometry performance at the junior secondary level. Consequently, pertinent stakeholders in mathematics education ought to organize conferences and seminars to exhibit this advanced, software-driven training.

CONCLUSION

The study's findings led to the conclusion that Basic 8 students' geometry performance improved with the use of Geoboard during geometrical classes. Furthermore, using Geoboard bridges the gender gap in students' geometry performances reported in earlier studies reviewed. Hence, mathematics teachers must possess a solid understanding of mathematical software like Geoboard to maximize and maintain the academic progress of both male and female students in geometry.

REFERENCES

Age, T. J., & Machaba, M. F. (2023). Effect of mathematical software on senior secondary school students' achievement in geometry. ***Eureka: Social and Humanities 5***, 82–93. http://doi.org/10.21303/2504-5571.2023.003151

Age, T. J., & Machaba, M. F. (2024). Mathematical software: A panacea for improving senior. secondary school students' retention in geometrical constructions. ***Research in Educational Policy and Management***, ***6***(1), 238–254. https://doi.org/10.46303/repam.2024.15

Age, T. J., Iji, C. O., Abakpa, B. O., & Anyagh, P. I. (2021). Reinvigorating secondary school students' interest in geometry using GeoEnZo software (GS) in Benue State, Nigeria. ***Journal of Global Research in Education and Social Science, 5***(6), 1–9. https://ikprress.org/index.php/JOGRESS/article/view/7237

Akpan, I. I., Utibe, U. J., Babayemi, J. O., & Nelson, M. F. (2023). Effect of GeoBoard and charts on students' achievement in mathematics in Essien Udim, Akwa Ibom State, Nigeria. ***Journal of Research in Education and Society***, ***14***(2), 91–102. https://icidr.org.ng/index.php/Jres/article/view/1537

Alghadari, F., & Herman, T. (2018). The obstacles of geometric problem-solving on solid with vector and triangle approach. In ***Journal of Physics: Conference Series***, 1132, (1) 1–6. http://doi.org/10.1088/1742-6596/1132/1/012046

Eriksson, K. (2020). Gender Differences in the Interest in Mathematics Schoolwork Across 50 Countries. ***Frontiers in Psychology***, 11. https://doi.org/10.3389/fgsyg.2020.57809

Hengki, M., Jamiah, Y., & Yundari, Y. (2024). Enhancing senior high school students' visual imagery creativity in geometry through Geoboard. ***Indonesian Journal of Science and Mathematics Education***, ***7***(2), 361–372. https://doi.org/10.24042/ijsme.v7i2.22624

Jablonski, S., & Ludwig, M. (2023). Teaching and learning of geometry–A literature review. on current developments in theory and practice. ***Education Sciences, 13***(7), 682. https://doi.org/10.3390/educsci13070682

Ji, Z., Guo, K., & Song, S. (2024). Effects of dynamic mathematical software on students' performance: A three-level meta-analysis. ***Journal of Educational Computing Research, 62***(4), 1035-1060. https://doi.org/10.1177/07356331241226594

Kyabuntu, K. J., & Mbhiza, H. W. (2024). Rethinking the teaching of Euclidean geometry. ***Journal of Pedagogical Sociology and Psychology***, ***6***(3), 49-63. https://www.j-psp.com/article/rethinking-the-teaching-of-euclidean-geometry-14799

Makondo, P. V., Makondo, D. (2020). Causes of poor academic performance in mathematics at ordinary level: A case of Mavuzani High School, Zimbabwe. ***International Journal of Humanities and Social Science Invention, 9***(6), 10–18. https://doi.org/10.35629/7722-0906011018

Mario, R. S., Angélica, A. S. L., Manuel, S. P. J., Carmen, S. C. M., & Socorro, G. P. E. (2024). Geogebra software and playful strategies in mathematics learning in students of a state educational entity of Piura, 2023. ***Migration Letters***, ***21***(S3), 1037–1049. https://doi.org/10.59670/ml.v20i8.6885

Noverianto, B., Agoestanto, A., Dewi, N. R., & Mariani, S. (2024). Meta-analysis: The effect of the GeoGebra applet-assisted discovery learning model on students' mathematical problem-solving ability in geometry material. ***Mathline: Jurnal Matematika Dan Pendidikan Matematika***, ***9***(2), 331–346. https://doi.org/10.31943/mathline.v9i2.604

Okoye, G. N., & Onyeka, E. C. (2022). Application of Geotrigmetric Set and Geoboard on students' retention in mathematics in Rivers State Nigeria. ***African Journal of Educational Management,Teaching and Entrepreneurship Studies***, ***7***(2), 82–97. https://ajemates.org/index.php/ajemates/article/view/178

Poloamina, B. O., Otikor, M. S., & George, N. R. (2024). Concrete Geoboard manipulatives and junior secondary school students' performance in plane geometry in Port Harcort, Nigeria. ***International Journal of Multidisciplinary Research and Growth Evaluation, 5***(6), 1443–1449. https://www.allmultidisciplinaryjournal.com/uploads/archives/20250106190054_F-24-234.1.pdf

Sibiya, M. R. (2020). A reconsideration of the effectiveness of using geoboard in teaching Euclidean geometry. ***Eurasia Journal of Mathematics, Science and Technology Education***, ***16***(9), em1876. https://doi.org/10.29333/ejmste/8360

Tessema, G., Michael, K., & Areaya, S. (2024). Realist hands-on learning approach and its contributions to learners' conceptual understanding and problem-solving skills on solid geometry. ***Pedagogical Research, 9***(1), em0186. https://doi.org/10.29333/pr/14096

Usman, H., Yew, W. T., & Saleh, S. (2020). Effects of Van Hiele's phase-based teaching strategy and gender on pre-service mathematics teachers' geometry achievement in Niger State, Nigeria, ***International Journal of Pedagogical Development and Lifelong Learning***, ***1***(1) ep2006. http://doi.org/10.30935/ijpdll/8363.

West African Examination Council. (WAEC, 2022). ***General Mathematics, Paper 2.*** https://www.waeconline.org.ng/e-learning/Mathematics/maths235jw.html