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Effect of Maple Software and Geoboard on Students' Performance and Retention in Geometry in Obio/Akpor Local Government Area, Rivers State, Nigeria

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Abstract
The study investigated the effect of Maple Software and Geoboard on students' academic performance and retention of the concept of Geometry in Obio/Akpor Local Government Area of Rivers State. Two research questions and two hypotheses guided the study. The pre-test, post-test, quasi experimental design was adopted as the research design. Random sampling technique was used to select an intact class of Senior Secondary School 1 from each of two randomly selected schools in the study area, which yielded one hundred and eleven SS1 students as the sample for the study. The research instruments were the Geometry Performance Test and Geometry Retention Test. Kuder-Richardson 21 formula was used to obtain the reliability coefficient of 0.84 for Geometry Performance Test, while Geometry Retention Test is a reshuffled version of Geometry Performance Test. Mean and Standard deviation were used to answer the research questions while Analysis of Covariance was used to test the hypotheses at 0.05 level of significance. The findings revealed that Maple software significantly enhanced students' performance in Geometry, as well as the retention of the knowledge of Geometry more than Geoboard. Geoboard also had an enhancing effect on students' retention of the knowledge of the concept of Geometry. Based on the findings, the study recommends that the Maple software and Geoboard be integrated into the teaching and learning of Mathematics.

Keywords: Resources, Maple Software, Geoboard, Geometry, Students' Performance, Retention.

Introduction

Mathematics is one of the foundations of most science and technology disciplines in the educational system. It is so useful that it cuts across every facet of life, such that the ordinary man on the street needs the knowledge of Mathematics to carry out basic transactions in all of his endeavours. Mathematical concepts are involved and analyzed to obtain the desired results in counting numbers, buying and selling in markets, bank transactions, local and international financial businesses, etc. This is the fundamental reason Mathematics is one of the most important subjects in the education system (Muawiya & Umar, 2019). Mathematics, according to Hom and Gordon (2021) is defined as the heart of science and it is part of our daily lives. It is the science that deals with the description of shape, quality, and arrangement of numbers. Quinn (2022) described Mathematics as an expression of the human mind that reflects the active will, the completive reason, and the desire for aesthetic perfection. Wilkinson (2021) described it as the craft of creating new knowledge from the old, using deductive logic and abstraction. It is also the study of quantity and the discipline that includes natural numbers, plane, and solid geometry. As a science, it draws necessary conclusions.

The contribution of Mathematics is numerous considering the application in most subjects especially science such as Physics, Chemistry, and Biology. Mathematical principles are applied in the measurements and calculations of quantities in these disciplines. Social sciences like Economics, Psychology, and Sociology have fundamental bearing in Mathematics. Engineering, Computer Science, Telecommunication, and other related subjects thrive on mathematical principles, analysis, manipulation, and application of Mathematics (Murphy, 2023).

Mathematics consists of branches which include Arithmetic, Algebra, Geometry, Trigonometry, Statistics, and Calculus (Osaat, 2009). Geometry is one of the branches of Mathematics that is seen in our environment. It is the study of shapes, sizes, angles, and properties of shapes with dimensions (Merriam-Webster, 2021). Megan and Yuanxim (2023) defined geometry as the mathematical study of lines, shapes, and surfaces. Geometry is denoted from the Greek word “geo”, meaning earth and “metrein”, meaning to measure. This is simply put together to mean measuring the earth and what is in it. According to Muawiya and Umar (2019), the calculation aspects of Geometry are difficult and most students choose alternative questions to geometry questions. These difficulties experienced could be traced to the teaching and learning methods adopted by the teachers in classroom activities which in turn have contributed to the failure of students in Mathematics.

Over the years, Lecture method has been used to teach and learn Mathematics. Lecture method, which is one of the conventional teaching methods involves talking, reading, and writing on the chalkboard from well-prepared materials on a particular concept, hence nicknamed 'chalk and talk method'. It is not learner-centered but teacher-centered. Teachers barely use instructional resources when using Lecture method to teach. The method thus makes the students passive learners while the concentration on the teachers makes the teacher active during the lessons (Hom & Gordon, 2023). The method sometimes ends up being one-way communication where the students mainly listen to the teacher and take notes, leading to dull and boring lessons, as well as rote learning which does not guarantee comprehension and retention of the concepts taught. As such, there is a need for more learner-engaging and effective methods/strategies which employ interactive instructional resources for the teaching and learning of Mathematics.

Maple software application is a unique tool for educational development in many countries. Maple is a software built with a symbolic and numeric computing environment, programmed and designed with multi-paradigm programming language. The strategy outweighs the scientific or programming calculators used in mathematical calculations. Maple is used to solve scientific, differential, integral, matrix polynomial equations, and graphical equations (Maplesoft, 2019). Bray and Tangney (2017) believe that teaching Mathematics in a technology-controlled learning environment is more effective than the use of traditional teaching methods, which focus on paper and pencil. National Council of Teachers of Mathematics (NCTM) (2023) added that the integration of technology by teachers helps the students and teachers make sense in teaching and learning mathematics. Technology enhances the understanding of the students, captures their attention, and improves their mathematical skills (NCTM, 2023). The applications of Maple can be seen in graphic curve fitting, and calculation programming which can be applied to numerical analysis. Autograph can be used to plot coordinate geometry as well as rotation and reflection, vectors, graphs, differential equations, transformation probability, and statistics. Maple software application is an instructional tool that emphasizes computational aspects. Salleh and Zakaria (2016) described Maple software as the mathematical application software that can teach mathematical concepts and provide various instructional tools, including a powerful mathematical software package that includes graphics, computation, and programming. Maple can generate metacognitive cues or signals among students in learning integral calculus.

Manipulatives are concrete learning materials that allow students to comprehend abstract concepts by concretizing them (Laski et al. 2023). With the use of manipulatives, a relationship is established between the manipulatives and abstract mathematical concepts by offering concrete experiences (Byrnes et al., 2023) and eventually, providing long-term permanence of mathematical skills. McCarthy et al. (2023) asserted that manipulatives enable students to integrate their knowledge and associate them with their thoughts in order to understand mathematical concepts thoroughly. They contribute to students' communication with their mathematical thinking, bringing their mathematical ideas to a higher cognitive level. They also evoke amusement in the teaching process by providing active participation

of both students and teachers. Manipulatives can be used as instructional materials to facilitate teaching and learning of Mathematics. Looking at the positive contributions it makes, it also conceptualizes students' learning experiences. However, manipulatives do not only contribute to the cognitive aspect of the learner, but they also enhance the development of psychomotor skills by addressing several senses of the learner such as sight, touch, and hearing, inside and outside the class (Horan & Carr, 2018; McCarthy et al., 2023). As stated by Horan and Carr (2018), manipulatives should not be thought of as a remedy, providing an advantage against every difficulty that students face in Mathematics. Instead, according to McCarthy et al. (2023), teachers and students need to make common sense out of the manipulatives they will use. Otherwise, manipulatives would not go beyond being a means of entertainment alone and cannot help the learners comprehend any concept. Consequently, manipulatives should be understood and applied properly during teaching and learning. Manipulatives include geoboard, base-ten block, spinner, dice, and cards.

Geoboard is a manipulative used in teaching and learning geometry. A geoboard is made of boards with nails or pegs lined up in rows and columns (Hurst & Linsell, 2020). They can come in different sizes and colours. Geoboards are used by wrapping rubber bands around the nails or pegs to create shapes and learn geometry. Geoboard templates can also be printed. This takes away the point of physically handling a manipulative. Geoboards also help to identify simple geometric shapes such as squares, rectangles, circles, and triangles (McCarthy et al., 2023). In problem-solving and teaching patterning, geoboard is developed to determine the perimeter and symmetry. A geoboard is an effective tool to help students overcome misconceptions about area and perimeter. Geoboards are tremendously useful for students to learn about different concepts in geometry.

Evidence abounds in research about the effectiveness of the use of the Geoboard on the understanding and performance of students in mathematical concepts. Olajide et al. (2020) found that the students taught geometry using geoboard performed better than the students taught using conventional method, though the difference in performance was not significant. Abari and Andrew (2021) found that the use of geoboard significantly enhanced the performance of JSS students in Geometry more than Lecture method. Similarly, Adesokan (2023) found that geoboard significantly enhanced the performance of JSS1 students in Geometry. The students who were taught Geometry using geoboard performed significantly better than students taught without geoboard. Owusu and Sallah (2023) found that Geoboard significantly enhanced the performance of pre-service teachers in plane geometry. Wasagu et al. (2023) found that geoboard enhanced the academic achievement of primary four pupils in the measurements of areas of some 2-dimensional shapes more than lecture method. Ezeamaenyi and Anaeche (2022) found that Geoboard increased students' achievement in identifying and differentiating polygons, as well as describing and locating coordinate points. Peñanueva et al. (2023) found that Geoboard significantly enhanced the overall performance of grade III elementary pupils in the Mathematics concept of Fractions equal to one and greater than one more than the conventional teaching method. Akpan et al. (2023) found a significant difference between the students taught using Geoboard and Charts in their achievement in Mathematics, in favour of the students taught using the geoboard. Onyeka et al. (2022) found that geoboard significantly enhanced students' performance in mathematics more than the deductive method. Onyeka et al. (2022) however, found that geotrigmetric set significantly enhanced students' performance in mathematics more than geoboard.

Maple software has also been found effective in teaching and learning mathematical concepts. Deljuy (2021) found that Maple Software made the learning of algebraic and trigonometric curves drawing more effective than the traditional method among tenth-class students. Sallah (2021) found that the senior high school students taught using Maple software significantly outperformed their counterparts who were taught using the traditional method in calculus. Gamage and Williams (2024) found that the students taught Calculus using Maple software performed better than their

colleagues taught using lecture method. Yuliari et al. (2023) found a significant difference in the understanding of integral calculus between students taught using Maple software and those taught using classical learning. The use of Maple software improved students' understanding of the concept of integral calculus, while Sallah et al. (2023) found that the use of Maple software significantly enhanced student-teachers' understanding of differential calculus more than the use of the traditional method, consequently reducing their errors in differential calculus.

Concerning the retention of mathematical concepts, Okoye and Onyeka (2022) found that the application of Geoboard was more effective in enhancing students' retention of mathematics concepts than the use of Geotrigmetric set. Geoboard was also found to enhance students' retention of mathematics concepts more than the use of deductive teaching method, while Njoku et al. (2023) found that GeoTAN Instructional Software Package (GISP) which is an instructional software like Maple software, significantly enhanced students' retention of the knowledge of Geometry more than the conventional method.

Statement of the problem

The fact that Mathematics is one of the difficult and feared subjects despite its importance to the development of science and technology and consequently national development, has become a major concern over the years. The poor performance persistently recorded by secondary school students in Mathematics necessitated this research. From the West African Examination Council (WAEC) Chief Examiner's Report of 2018, as well as 2020 to 2023, the students who sat for the examinations expressed weaknesses in coordinate geometry, circle geometry, and plane geometry, consequent on inadequate knowledge of geometry. Could the type of instructional resources being used to teach mathematics lead to this persistent poor students' academic performance in geometry? Can a technological-based resource such as Maple Software help improve students' academic performance in geometry? This study therefore investigated the effect of Maple Software on secondary school students' academic performance and retention in Mathematics in Obio/Akpor Local Government Area, Rivers State.

Aim and Objectives of the study

The aim of this study was to investigate the effect of Maple software and Geoboard on students' performance and retention of the concept of Geometry. The specific objectives of the study were to:

1. investigate the effect of Maple software and Geoboard on students' academic performance in Geometry.
2. investigate the effect of Maple software and Geoboard on students' retention of the knowledge of the concept of Geometry.

Research Questions

The following research questions guided the study:

1. What is the difference between the academic performance of students taught Geometry using Maple software and those taught using Geoboard?
2. What difference exists between the students taught Geometry using Maple software and those taught using Geoboard in their retention of the knowledge of the concept of Geometry?

Hypotheses

The following hypotheses were tested at 0.05 level of significance:

1. There is no significant difference between the academic performance of students taught Geometry using Maple software and those taught using Geoboard.
2. There is no significant difference between the students taught using Maple software and those taught using Geoboard in their retention of the knowledge of the concept of Geometry.

Methodology

The research design used was pretest, post-test, quasi-experimental design. The population of this study consisted of two thousand four hundred and fifty-six (2456) Senior Secondary School 1 (SS1) students in Obio/Akpor Local Government Area of Rivers State.

The simple random sampling technique was used to select two Senior Secondary Schools in the Local Government Area. The first school was the experimental group while the second school was the control group. The random sampling technique was also used to select an intact class from each of the two schools. A total of one hundred and eleven (111) SS1 students formed the sample of the study. The experimental group consisted of fifty-five (55) students made up of twenty – three (23) male students and thirty-two (32) female students. The control group consisted of fifty-five (56) students made up of twenty-two (22) male students and thirty-four (34) female students. In this study, the independent variable was Instructional resource (Maple Software and Geoboard) while academic performance and retention are the dependent variables.

The research instruments for this study were validated performance tests titled 'Geometry Performance Test' (GPT), and 'Geometry Retention Test' (GRT). GPT was a researcher – developed instrument with two sections A and B. Section A obtained the bio-data of the students while Section B contained 50 multiple-choice questions, intended to measure the students' performance in Geometry. Each correct answer attracted 2 marks while each wrong answer attracted zero mark. The maximum score obtainable was 100% while the lowest score obtainable was zero. GRT is a reshuffled version of GPT. A reliability coefficient of 0.84 was obtained for GPT using Kuder-Richardson 21 (KR-21).

The Geometry Performance Test was administered to the students in each group as Pretest, after which the Experimental group was taught Geometry using Maple software, while the control group was taught Geometry using Geoboard. Thereafter, the Geometry Performance Test was administered to the students in each group as Post-test. After two weeks, the Geometry Retention Test was then administered to the students in each group as Post post-test. The students' scores for the Pretest, Post-test, and Post post-test constituted the data for the study. Mean and standard deviation were used to answer the research questions while Analysis of Covariance (ANCOVA) was used to test the hypotheses.

Results

Research Questions

Research Question 1: What is the difference between the academic performance of students taught Geometry using Maple software and those taught using Geoboard?

Table 1: Mean values and Standard deviation of students' academic performance classified by instructional resource.

Instructional Resource		Pretest	Post Test	Mean Gain (Performance)
Maple Software	Mean	41.6364	58.0909	16.4545
	Std. Deviation	5.2753	6.8375	7.6178
	N	55	55	55
Geoboard	Mean	39.4643	48.5714	9.1071
	Std. Deviation	6.8542	11.4302	11.5250
	N	56	56	56

Table 1 reveals that the students taught Geometry using Maple software had a mean gain of 16.45 and standard deviation of 7.62 (Mg = 16.45, SD = 7.62) while the students taught Geometry using Geoboard had a mean gain of 9.11 and standard deviation of 11.53 (Mg = 9.11, SD = 11.53). These results show that the students taught Geometry using Maple software had a better academic performance than the students taught Geometry using Geoboard. This indicates that Maple software enhanced students' academic performance in Geometry more than Geoboard.

Research Question 2: What difference exists between the students taught Geometry using Maple software and those taught using Geoboard in their retention of the knowledge of the concept of Geometry?

Table 2: Mean values and Standard deviation of students' retention classified by instructional resource.

Instructional Resource		Post Test	Post-Post Test	Mean Gain (Retention)
Maple Software	Mean	58.0909	74.4545	16.3636
	Std. Deviation	6.8375	10.4825	11.1162
	N	55	55	55
Geoboard	Mean	48.5714	65.8036	17.2321
	Std. Deviation	11.4302	10.1254	15.0430
	N	56	56	56

Table 2 reveals that the students taught Geometry using Maple software had a mean gain of 16.37 and a standard deviation of 11.12 (Mg = 16.37, SD = 11.12) while the students taught Geometry using Geoboard had a mean gain of 17.23 and a standard deviation of 15.04 (Mg = 17.23, SD = 15.04). These results show that the students taught Geometry using Geoboard retained the knowledge more than the students taught using Maple software. This indicates that Geoboard enhanced students' retention of the knowledge of the concept of Geometry more than Maple software.

Hypotheses

Hypothesis 1: There is no significant difference between the academic performance of students taught Geometry using Maple software and those taught using Geoboard.

Table 3: Summary of Analysis of Covariance of students' academic performance classified by Instructional Resource using Pretest as Covariate

Tests of Between-Subjects Effects

Dependent Variable: Post Test

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	3204.299[a]	2	1602.150	19.182	0.000
Intercept	3269.030	1	3269.030	39.139	0.000
Pretest	689.784	1	689.784	8.259	0.005
Instructional Resource	2001.077	1	2001.077	23.958	0.000
Error	9020.476	108	83.523		
Total	327425.000	111			
Corrected Total	12224.775	110			

a. R Squared = 0.262 (Adjusted R Squared = 0.248)

Table 3 reveals a value of $F_{1,108} = 23.96$, $p = 0.00$ ($p < 0.05$) for the effect of Instructional resource on students' academic performance in Geometry. The null hypothesis is therefore rejected, indicating that, there is a significant difference between the academic performance of students taught Geometry using Maple software and those taught using Geoboard.

Table 4: Post Hoc analysis of students' academic performance classified by instructional resource.

Pairwise Comparisons

Dependent Variable: Post Test

(I) Instructional Resource	(J) Instructional Resource	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
Maple Software	Geoboard	8.627*	1.763	0.000	5.133	12.121
Geoboard	Maple Software	-8.627*	1.763	0.000	-12.121	-5.133

Based on estimated marginal means

*. The mean difference is significant at the 0.05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Table 4, which shows the Least Significant Difference Post hoc analysis of students' performance classified by Instructional resource, reveals a mean difference of 8.63 and a p-value of 0.00 ($p < 0.05$) between the effect of Maple software and Geoboard on students' academic performance in Geometry. This indicates that the students taught Geometry using Maple software contributed more to the significant difference between the effects of the instructional resources on students' academic performance.

Hypothesis 2: There is no significant difference between the students taught using Maple software and those taught using Geoboard in their retention of the knowledge of the concept of Geometry.

Table 5: Summary of Analysis of Covariance of students' retention classified by instructional resource using Posttest as Covariate.

Tests of Between-Subjects Effects

Dependent Variable: Post-Post Test

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2197.192[a]	2	1098.596	10.361	0.000
Intercept	13645.735	1	13645.735	128.689	0.000
Posttest	120.569	1	120.569	1.137	0.289
Instructional Resource	1269.774	1	1269.774	11.975	0.001
Error	11451.907	108	106.036		
Total	558950.000	111			
Corrected Total	13649.099	110			

a. R Squared = 0.161 (Adjusted R Squared = 0.145)

Table 5 reveals a value of $F_{1,108} = 11.98$, $p = 0.001$ ($p < 0.05$) for the effect of instructional resource on students' retention of the concept of Geometry. The null hypothesis is therefore rejected, indicating that, there is a significant difference between the students taught using Maple software and those taught using Geoboard in their retention of the concept of Geometry.

Table 6: Post Hoc analysis of students' retention classified by instructional resource.

Pairwise Comparisons

Dependent Variable: Post-Post Test

(I) Instructional Resource	(J) Instructional Resource	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
Maple Software	Geoboard	7.590*	2.193	0.001	3.243	11.938
Geoboard	Maple Software	-7.590*	2.193	0.001	-11.938	-3.243

Based on estimated marginal means

*. The mean difference is significant at the 0.05 level.

b. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Table 6, which shows the Least Significant Difference Post hoc analysis of students' retention classified by instructional resource, reveals a mean difference of 7.59 and a p-value of 0.001 ($p < 0.05$) between the effect of Maple software and Geoboard on students' retention of the concept of Geometry. This indicates that the students taught the concept of Geometry using Maple software contributed more to the significant difference between the effects of the instructional resources on students' retention of the knowledge of the concept of Geometry.

Discussion

The findings of this study revealed that the students taught Geometry using Maple software had a

significantly better academic performance than the students taught Geometry using Geoboard. This indicates that Maple software significantly enhanced students' academic performance in Geometry more than Geoboard. This finding may be due to the technologically interactive nature of the Maple software because the students are digital natives who are very comfortable working with electronic devices and technologies. This finding is in agreement with the finding of Deljuy (2021) who found that Maple Software was more effective in the learning of algebraic and trigonometric curves drawing than the traditional method. Similarly, the finding aligns with the findings of Sallah (2021), as well as Gamage and Williams (2024) who found that the students taught Calculus using Maple software performed better than their colleagues taught using the lecture method. In the same vein, the finding is supported by the finding of Yuliari et al. (2023) who found a significant difference in the understanding of integral calculus between students taught using Maple software and those who were taught using classical learning, in favour of the students taught using Maple software, and Sallah et al. (2023) who found that the use of maple software significantly enhanced the understanding of student-teachers in differential calculus more than the use of the traditional method, consequently reducing their errors in differential calculus.

The findings of this study also revealed that there is a significant difference between the students taught using Maple software and those taught using Geoboard in their retention of the concept of Geometry, in favour of the students taught using Maple software. This finding may also be due to the technologically interactive nature of the Maple software because the students are digital natives who are very comfortable working with technology and virtual reality, which makes it easier for repeated practice, and consequently a better retention of the knowledge acquired. This finding is in agreement with the finding of Njoku et al. (2023) that GeoTAN Instructional Software Package (GISP) which is an instructional software like Maple software, significantly enhanced students' retention of the knowledge of Geometry more than the conventional method.

The findings of this study further revealed that Geoboard had an enhancing effect on students' retention of the concept of Geometry. This finding may be due to the hands-on nature of the Geoboard which enabled the active participation of the students in the teaching and learning process. This finding is in agreement with the finding of Okoye and Onyeka (2022) who found that the application of Geoboard was more effective in enhancing students' retention of mathematics concepts than the use of Geotrigmetric set. Similarly, the finding is in consonance with the finding of Okoye and Onyeka (2022) who found that Geoboard enhanced students' retention of mathematics concepts more than the deductive teaching method.

Conclusion

This study investigated the effect of Maple software and Geoboard on students' academic performance and retention of the concept of Geometry. The findings of the study revealed that Maple software significantly enhanced students' academic performance in Geometry, as well as the retention of the knowledge of Geometry. Geoboard also had an enhancing effect on students' retention of the concept of Geometry. Maple software and Geoboard have been proven in this study to be effective in enhancing the academic performance of students in Geometry, as well as the retention of the knowledge of Geometry by students. The academic performance and retention of Mathematical concepts will therefore be enhanced if these two instructional resources are used by Mathematics teachers in the teaching and learning of Mathematics.

Based on the findings of this study, the following recommendations were made:

1. Mathematics teachers should integrate instructional software and technologies such as Maple software in the teaching and learning of Mathematics concepts.
2. Mathematics teachers should incorporate the use of interactive instructional resources such as Geoboard in the teaching and learning of Geometry.

References

Abari, M. T., & Andrew, K. D. (2021). Effects of Geoboard on the performance of Junior

Secondary School Students in Geometry in Makurdi Metropolis of Benue State. *International Journal of Advances in Engineering and Management (IJAEM), 3*(12), 225-228.

Adesokan, R. T. (2023). Investigating the effectiveness of Geoboard manipulatives on JSS1 students' performance in plane geometry. A study of Katsina metropolis. *Sapentia Foundation Journal of Education, Sciences and Gender Studies (SFJESGS), 5*(4), 273-280.

Akpan, I. I., Utibe, U. J., & Nelson, M. F. (2023). Effect of geoboard and charts on students' achievement in Mathematics in Essien Udim, Akwa Ibom Stste, Nigeria. *Journal of Research in Education and Society, 14*(2), 91-102.

Bray, A., & Tangney, B. (2017). Enhancing student engagement through the affordances of mobile technology: A 21st century learning perspective on realistic mathematics education. *Mathematics Education Research Journal, 28*(1), 173–197.

Byrne, E. M., Jensen, H. Thomsen, B.S., & Ramchandani, P. G. (2023). Educational interventions involving physical manipulatives for improving children's learning and development: A scoping review. *Review of Education,*1-42. https://doi:org/10.1002/rev3.3400 www.onlinelibrary.wiley.com

Deljuy, A. B. (2021). The Maple 15 Learning Software effect on the conceptual realization, and developing the Afghanistan students' knowledge through curves: A case study in Samangan. *International Journal of Scientific and Research Publications, 11*(9), 45-49. http://dx.doi.org/10.29322/IJSRP.11.09.2021.p11707 www.ijsrp.org

Ezeamaenyi, M. O. N., & Anaeche, K. C. (2022). Effects of geo-board game on academic achievement of Junior Secondary Students in selected mathematical concepts in Ideato North Local Government Area, Imo State. *https:/eprints.gouni.edu.ng*

Gamage, T. Williams, C. (2024). Maple software and undergraduate mathematics students' performance and attitude in calculus in Bayelsa State. *International Journal of Research and Scientific Innovation (IJRSI), 11*(11), 1028-1040. doi:10.51244/IJRSI www.rsisinternational.org

Hom, E.J., & Gordon, J. (2021). *What is Mathematics?* www.livescience.com

Horan, E. & Carr, M. (2018). An intervention study on kindergarten mathematics with manipulatives interval. *Journal of Education Psychology, 7*(3), 286-316. http://www.edtechbook.org

Hurst, C. & Linsell, C. (2020). Manipulatives and multiplicative thinking. *European Journal of STEM Education, 5*(1), 04. https://doi:10.20897/5808

Laski, E. V., Jor'dan, J. R., Daoust, C., & Murray, A. K. (2015). What makes mathematics manipulatives effective? Lessons from cognitive science and Montessori education. *SAGE Open, 5*(2),1-8. doi:10.1177/2158244015589588 https://journals.sagepub.com

Maple Soft (2019). *History of maple*. www.maplesoft.com.

McCarthy, O., Firestone, M., & Pisano, G. (2023). *Manipulatives in educational concept, techniques and uses.* https://study.com

Megan, K., & Yuanxim, Y. A. (2023). *Geometry definition, history and branches.* http://study.com

Merriam-Webster (2021). *What is a school?* https://www.merriam-webster.com

Muawiya, H. U., & Umar I. O. (2019). Effect of jurisprudent-model of instruction on performance and interest in geometry concept among students' in Nassarawa State, Nigeria. *Proceedings of Mathematical Association of Nigeria (MAN) 56th Annual National Conference held in September 2019.*

Murphy, P. A. (2023). *Donald Hoffman is lost in maths: Decorated permutations, markov chains… and idealism.* https://medium.com

National Council of Teachers of Mathematics (2023). *The role of technology in the teaching and learning of Mathematics.*

National Council of Teachers of Mathematics.

Njoku, C., Okri, J. A. Emeka, S. I. (2023). Enhancing secondary school students' retention in geometry through the use of GeoTAN instructional software package. *Inter-Disciplinary Journal of Science Education (IJ-SED), 5*(1), 42-51.

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.

Olajide, D., Ekwueme, C. O., & Ndioho, O. F. (2020). Geoboard application on geometry teaching and Senior Secondary School students' academic performance in Degema Local Government Area, Rivers State. *EPRA International Journal of Multidisciplinary Research (IJMR), 6*(3), 262-268.

Onyeka, E. C., Okoye, G. N., & Ndubuisi, E. E. (2022). Comparative effect of geotrigmetric set and geoboard on students' academic achievement in Mathematics in Rivers State, Nigeria. *Unizik Journal of Educational Research and Policy Studies, 14*(3), 55-68.

Osaat, S. O. (2009). *Mathematics therapy: A pedagogical approach*. Hiddenmanna Publishing house.

Owusu, A., & Sallah, E. K. (2023). Effect of using Geoboard in teaching plane geometry on the performance of pre-service teachers. *IOSR Journal of Mathematics (IOSR- JM), 20*(4), 33-39.

Peñanueva, N. A., Cautivo, R. G., & Pingot, L. P. S. (2023). The use of geoboard to improve the mathematical performance of the grade III pupils in Cateel Central Elementary School. *International Journal of Advance Research and Innovative Ideas in Education (IJARIIE), 9*(3), 4839-4855.

Quinn, J. (2022). *What is Mathematics?* Mathematical Association of America. https://www.mathvalues.org

Sallah, E. K. (2021). Use of Maple Software to Reduce Senior High School Students' Errors in Integral Calculus. *African Journal of Educational Studies in Mathematics and Sciences, 17*(2), 51-59. DOI: https://dx.doi.org/10.4314/ajesms.v17i2.5

Sallah, E. K., Joshua, K. S., & Owusu, A. (2023). Use of maple software to reduce student teachers' errors in differential calculus. *African Journal of Mathematics and Statistics Studies, 4*(3), 32-46. https://doi.org/10.52589/AJMSS-KBCFARPR

Salleh, T. S., & Zakaria, E. (2016). The Effects of Maple Integrated Strategy on Engineering Technology Students' Understanding of Integral Calculus. *Turkish Online Journal of Educational Technology-TOJET, 15*(3), 183-194.

Wasagu, S. U., Abdullahi, A., & Dutsin-ma, S. H. (2023). *Impact of geoboard on academic achievement in measurement of areas of some 2-dimensional shapes at Basic Education level in Batagarawa Local Government, Katsina State, 1-9.*https://www.researchgate.net/publication/371608036

West African Examination Council (WAEC) (2018). *Chief Examiner's Report for Mathematics*. waeconline.org.ng/e learning/Mathematics.

West African Examination Council (WAEC) (2020). *Chief Examiner's Report for Mathematics*. waeconline.org.ng/e-learning/Mathematics.

West African Examination Council (WAEC) (2021). *Chief Examiner's Report for Mathematics*. waeconline.org.ng/e learning/Mathematics.

West African Examination Council (WAEC) (2022). *Chief Examiner's Report for Mathematics*. waeconline.org.ng/e learning/Mathematics.

West African Examination Council (WAEC) (2023). *Chief Examiner's Report for Mathematics*. waeconline.org.ng/e-learning/Mathematics.

Wilkinson, J. E. (2021). Contemporary challenges for education in early childhood. In O. M.

Alegre de la Rosa, L. M. V. Angulo & C. Giambrone (Eds). *Education in childhood*, 1-13. https://dx.doi.org/10.5772/intechopen.98903

Yuliari, R., Arifin, S., Kusumah, Y. S., & Dahlan, J. (2023). The effectiveness of learning mathematics assisted by maple software on understanding the concepts of calculus: An experimental study of vocational school students in Kuningan. *Conference Proceedings of the 3rd International Conference on Science, Engineering and Technology (CSET 2023), held at Palembang, Indonesia.* 3052. doi://10.1063/5.0201049 https://www.researchgate.net/publication/380059423