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Application of Simulation Software and Mathematics Learning Outcome of Students in Higher Education in Rivers State, Nigeria

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Abstract
This study was conducted to examine the effect of simulation software on students' mathematics learning outcome in higher education in Rivers State, Nigeria. Two (2) objectives, research questions and two corresponding null hypotheses were used to give the study a focus. The connectivist theory was the anchor for this study. Quasi experimental research design was used. The population consisted of all five hundred and sixteen (516) Level 200 mathematics students in the tertiary institutions in Rivers State. A purposive sampling method was employed to select a sample of 138 second-year students from two higher education institutions in Rivers State. Data collection was carried out using a Geometrical Transformation Achievement Test (GTAT). The instrument underwent face and content validation. Kuder Richardson 21 was used to ascertain the reliability of the instrument which was 0.83. The study included one experimental group and one control group. The experimental group was taught geometrical transformation using Geometer's sketchpad simulation software while the control group was taught using charts. The students in both groups were given pretest, taught the concept of geometrical transformation which included rotation, reflection and translation of 2D and 3D geometrical figures. After the treatment, a posttest of reshuffled GTAT was given to students in both experimental and control groups. Analysis was done using mean, StD and ANCOVA at 0.05 significant level. The result showed that students taught with simulation software had a higher performance than those taught with charts with a statistically significant difference. The result also showed that the male students taught with simulation software had a higher performance than the female students with no statistically significant difference. The study concluded that use of simulation software such as Geometer's sketchpad improved the performance of students in mathematics. From the findings, the study recommended that simulation software should be used to teach mathematical concepts when suitable, and female students should be motivated to utilize technology for learning these concepts.

Keywords: Simulation software, Geometer Sketchpad, Higher Education, Learning Outcome, Mathematics

Introduction

The teaching of mathematics cannot be isolated from the drift of the society. In today's world, technology is integrated into every level of education across the globe. Employing technology to teach mathematics at the tertiary level requires familiarity with computers, the internet, general and subject-specific software or applications. According to Scharaldi (2020) [13], utilizing technological tools in mathematics instruction has been revealed to improve students' performance and retention in the subject. Mathematics education in higher institutions should focus on innovative approaches that cultivate 21st-century skills among students. To groom students that will become successful members of the global society, academic instructions must embrace the four C's of the 21st century skills (communication, collaboration, critical thinking and creative thinking).

Strobel Education (2023) [15] opined that innovative instructional strategies are the strategies that can be employed to create an engaging learning environment that encourages active learning and experiences. Integration of technology comes to mind since the use of technology is one of the hallmark of the 21st century. One of the innovative strategies used in the classrooms today is simulation-based.

Simulation-based instruction involves the use of simulation software to carry out teaching. This indicates that simulation-based instruction involves the use of technology, hands-on activities, and other materials that help students learn academic concepts and phenomena meaningfully. A simulation mimics the functioning of a real-world process or system throughout a period of time. Simulation-based instruction operates on the principle that one cannot learn to do something by just reading or hearing about it (Keinab & Abidire, 2019) [8]. Modern technology has transformed the teaching and learning of mathematics in higher education institutions. Modern technology provides a platform which enables students to experience hands-on learning, interactive simulations and digital resources (Ochilov, 2023) [11]. In computer-based learning settings, students can simulate, validate, and model mathematical relationships.

Simulation instruction in mathematics refers to the study of a system or the components of the system by manipulating, observing, recording its mathematical representation to analyze the behavior of the system with the aid of computer and software. Simply put, simulation can be said to be an imagined system or a computerized model. The major thing simulation software does is that it helps the problem solver to predict the behavior of a given system. Simulation can be experimented using mathematical formulae, algorithms and geometrical visualization. It can also be experimented using events that take place in our environment such as weather forecasting, flight simulators used for training pilots, car crash modelling, traffic light timing, manufacture of furnitures, bridges, high-rise buildings etc. The use of simulation to carry out mathematical instruction entails that experiments are performed on models of the original system, as against the original system itself. Williams-Wood (2021) [19] stated that one of the advantages of simulation is that it allows the exploration of "what if" queries and scenarios without directly experimenting on the real system.

Dynamic mathematics instruction using software enhances students' spatial visualization skills more effectively than instruction based on physical manipulatives. Geometer's Sketchpad, a versatile mathematics software, can model concepts in geometry, algebra, and calculus. It therefore becomes imperative that some mathematics concepts be taught by employing technological gadgets and softwares. Geometer's Sketchpad stands as a premier software globally used for mathematics education, particularly for exploring geometry, algebra, calculus, and various other mathematical domains. Geometer's Sketchpad is a versatile mathematics tool designed for teaching concepts like constructing and manipulating geometric shapes. It enables the creation and exploration of mathematical models, objects, diagrams, and graphs. Tammy (2022) [17] posited that Geometer's sketchpad makes mathematics more meaningful and memorable for the learners.

George and Charles-Ogan (2023) [4] asserted that geometry, which is a branch of mathematics, explores the characteristics of space, including distance, shape, size, and the relative arrangement of figures. Geometry was initially developed to represent the physical world, which is abundant with diverse geometric shapes. Geometrical shapes can be transformed mathematically. In mathematics, a transformation is a method of changing a figure or object by applying a set of rules or operations. Transformations can be applied to various mathematical objects such as geometric shapes (points, lines, triangles etc), functions (graph, equations), matrices (linear transformations) and vectors (vector additions, scalar multiplications etc). The different types of transformations are:

1. Translations (moving a figure)
2. Rotations (rotating a figure around a fixed point or axis)
3. Reflections (mirroring a figure over a line or plane)
4. Scaling (resizing a figure)
5. Shear transformations (distorting a figure by applying skew)
6. Affine transformations (combining translations, rotations and scaling)
7. Non-linear transformations (more complex transformations, such as exponential or trigonometric functions).

George (2022) [5] opined that most students perform poorly in mathematics due to inability to visualize mathematical objects. Simulation software aids students in visualizing mathematical objects and processes that may be challenging to visualize physically. Geometer's Sketchpad, for example, facilitates conceptual understanding in mathematics by enabling experimental practice and visualization of mathematical topics. It is expected that students' performance in mathematics will be improved when simulation software such as Geometer's sketchpad is used to simulate geometrical transformation such as rotation, reflection and translation. Students performance can be improved upon when they comprehend the nitty gritty involved in the flipping of a point or figure over a line of reflection. The use of Geomter's sketchpad to simulate transformation of geometrical objects will help to improve students' performance in geometry because it will help them to visualize the images (pre image, on-point image and post image) of models. Students' of higher education will also be able to apply transformation in real-life situation.

The research finding of Kotu and Weldeyesus (2022) [9] showed that the use of Geometer's sketchpad simulation software to carry out instruction in geometry improved the students' learning of the taught concept, motivation and problem-solving ability. Gyedu *et al*. (2020) [6] examined the impact of Geometer's Sketchpad on students' performance in quadratic graphing and discovered that it enhanced their performance in this area. Ji *et al*. (2024) [7] explored the impact of dynamic mathematical software on students' mathematics performance and found that the software positively influenced their outcomes. Therefore, it was suggested that teachers should be careful and thorough in designing their classroom lessons for instruction. Based on their findings, Udofia and Uko (2018) [18] suggested that simulation software could serve as a valuable supplement to traditional methods in teaching mathematical concepts.

Marafa and Sulaiman (2023) [10] carried out a study on the effect of computer simulations and instructional games on the academic achievement of senior secondary school students in mathematics at Sokoto, Nigeria and found out that computer simulation has a statistically significant effect on students' academic performance in mathematics. The study concluded based on its findings that the use of simulation-based instruction to teach mathematics motivated and sustained students' interest in the subject and thereby improved their academic performance in mathematics.

This study was anchored on connectivist theory**.** Connectivist theory was propounded by George Siemens in 2005. The theory posits that technology is a crucial component of the learning method, and that continuous connectivity allows learners to make informed choices about their education. This theory upholds that students can learn academic contents from technological devices. Connectivism is a modern learning theory designed for the digital era. Its four core principles are autonomy, connectedness, diversity, and openness. Connectivism theory is a framework that promotes learning in the digital era. The theory advocates for students to integrate ideas, theories, and general information effectively. Connectivism promotes learning that extends beyond the individual, leveraging online networks, social media platforms, and information databases. The use of connectivism is effective in promotion of hands-on activities, develop students' networking skills, collaborative learning and self-directed learning.

Statement of the Problem

Mathematics is one school subject that has always been perceived difficult by students at all levels of education. This has led to poor performance of students in mathematics at the primary and secondary levels of education. The mathematics performance of students in the tertiary institution has also followed suit just the way it is poor at the lower levels of education. There are various methods and strategies that can be employed to teach mathematics due to accumulation of information, increase and complexity of knowledge. The teaching of mathematics in tertiary institutions suffers the problem of traditional teaching methods. Mathematics tutors have steered clear of utilizing contemporary technology for their instructional practices. This poses a problem because the students may have the need to learn and visualize mathematics concepts when they are simulated using software packages. There abound mathematics software packages that can be employed to simulate geometrical objects for the visualization of the taught concepts. The innovation in this research is that a mathematics software (Geometer's sketchpad) which has not been commonly used to teach mathematics concept is employed. So many researchers have employed mathematics software such as GeoGebra to teach mathematics as if that is the only software that exist.

It is based on this backdrop that this study investigated application of simulation software such as Geometer's Sketchpad to improve mathematics learning in higher education.

Objectives of the Study

The objectives were to

1. Ascertain the difference in the mean score performance of students taught mathematics using simulation software and those taught using chart-based instruction.
2. Ascertain the difference in the mean score performance of the male and female students taught mathematics using simulation software.

Research Questions

1. What is the difference in the mean score performance of students taught mathematics using simulation software and those taught using chart-based instruction?
2. What is the difference in the mean score performance of the male and female students taught mathematics using simulation software?

Hypotheses

The hypotheses were tested at .05 significant level.

H_{O1}: There is no significant difference between the mean score performance of students taught mathematics using simulation software and those taught using chart-based instruction.

H_{O2}: There is no significant difference between the mean score performance of the male and female students taught mathematics using simulation software.

Research Method

This study employed a quasi-experimental research design which made use of intact classes. The population of the study consisted of all five hundred and sixteen (516) Level 200 mathematics students in all the tertiary institutions in Rivers State. Using purposive sampling, a sample of one hundred and thirty eight (138) Level 200 students was selected from two tertiary institutions in Rivers State. Data was gathered using a set of 25-item multiple-choice questions which was titled "Geometrical Transformation Achievement Test" (GTAT). The instrument underwent face and content validation by three experts in applied mathematics and mathematics education respectively. The reliability of GTAT was determined using the Kuder Richardson Formula 21 by involving a group of twenty students that were not part of the main study. An internal consistency of 0.83 was established for GTAT. The study made use of one Experimental Group (E.G.) and one Control Group (C.G.). The E.G. learnt geometrical transformations with Geometer's Sketchpad simulation software, while the C.G. learnt same geometrical transformations using traditional instructional charts. The students in both groups were given pretest, taught the concept of geometrical transformation which included rotation, reflection and translation of 2D and 3D geometrical figures. After the treatment, a posttest of reshuffled GTAT was given to students in both experimental and control groups. The research assistants that were used for study were the intact class tutors of the sample. Analysis was done using mean, standard deviation and ANCOVA at 0.05 significant level.

Results

Table 1: Mean and StD on the mean score performance of students taught geometrical transformation using SIS and those taught using CBI

Group	N	Pretest		Posttest		Performance Gain	
		Mean	StD	Mean	StD	Mean	StD
Simulation Software	66	36.82	10.63	61.95	14.24	25.13	11.02
Chart-based Instruction	72	37.15	12.50	55.62	13.19	18.47	12.44

SIS = Simulation Software
CBI =Chart-based Instruction

The information in table 1 showed that the students that were taught geometrical transformation with simulation software in the E.G. had a performance mean gain of 25.13 with a standard deviation, StD =11.02. The students that were taught same concept with charts in the C.G. had a performance mean gain of 18.47 with StD = 12.44. The data in table 1 revealed that students who received instruction via simulation software outperformed those who were taught using charts.

Table 2: Mean and StD on the mean score performance of male and female students taught geometrical transformation using SIS

Group	Gender	N	Pretest		Posttest		Performance Gain	
			Mean	StD	Mean	StD	Mean	StD
Simulation Software	Male	37	34.01	12.35	63.65	12.29	29.64	11.41
	Female	29	39.63	10.82	60.25	10.64	28.62	13.85

The information in table 2 showed that the male students that were taught geometrical transformation with simulation software in the E.G. had a performance mean gain of 29.64 with a standard deviation, StD =11.41. The female students that were taught same concept in same E.G. with simulation software had a performance mean gain of 28.62 with a standard deviation, StD = 13.85. The data in table 2 indicated that male students who were instructed using simulation software outperformed their female counterparts within the same group.

Table 3: Summary of ANCOVA on difference between performance of students taught geometrical transformation using SIS and those taught using CBI

Source	Sum of Squares	Df	Mean Square	F	Sig.	η^2
Corrected Model	2461.106[a]	2	1230.553	31.131	.000	.471
Intercept	7975.983	1	7975.983	201.779	.000	.742
Pretest	247.535	1	247.535	6.262	.015	.082
Group	2185.481	1	2185.481	55.289	.000	.441
Error	2766.976	135	39.528			
Total	263250.000	138				
Corrected Total	5228.082	137				

a. R Squared = .421 (Adjusted R Squared = .453)

Table 3 showed the summary of ANCOVA on the difference between the performance of the students taught geometrical transformation using simulation software in the E.G. and chart-based instruction in the C.G. The result showed that a significant difference existed between the performance of students that were taught geometrical transformation with simulation software and those that were taught with CBI ($F_{1, 135}$ = 55.289, p =.000; p<.05, η^2 = .441). Since p-value < .05, H_{O1} was therefore rejected.

Table 4: Summary of ANCOVA on the difference in the performance of the male and the female students taught geometrical transformation using SIS

Source	Sum of Squares	Df	Mean Square	F	Sig.	η^2
Corrected Model	2227.21[a]	2	1113.60	13.34	.00	.43
Intercept	3784.98	1	3784.98	47.03	.00	.23
Pre test	2160.45	1	2160.45	26.85	.00	.40
Gender	16.73	1	16.73	0.21	.08	.07
Error	4884.581	63	77.533			
Total	353520.000	66				
Corrected Total	8489.939	65				

a. Group = Simulation Software
b. R Squared = .626 (Adjusted R Squared = .513)

Table 4 showed the summary of analysis of covariance on the difference between the performance of the male and the female students taught geometrical transformation with simulation software in the E.G. The result showed that no significant difference exist between the performance mean score of students taught geometrical transformation based on gender (F1,63= 0.21; p =.08 > .05; partial eta squared = .07). Since p-value > .05, H_{O2} was therefore retained.

Discussion of Findings

The study's result showed that students in the E.G., who learned geometrical transformation using Geometer's

Sketchpad simulation software, outperformed those in the C.G., who were taught using traditional charts. This was revealed in table 1 where the performance (mean gain = 25.13) of those taught with Geometer's sketchpad simulation software was higher than that of the students taught with charts in the C.G. (mean gain = 18.47). This finding agrees with the research evidences of Alabi *et al*. (2023) [2]; Talan (2021) [16]; Udofia and Uko (2018) [18] whose findings showed that the integration of simulation software in the teaching and learning of mathematics improved students' academic achievement and academic performance respectively. Also, in agreement with this result is that of Gamage and Charles-Ogan (2019) [3] which showed that use of GeoGebra to simulate mathematical curriculum contents linked to circle geometry improved the performance of secondary students in the taught contents. However, this finding varies with the finding of Onyeukwu (2020) [12] which revealed that simulation software did not improve students' performance in mathematics but rather chart-based instruction did. The reason for this variation could be due to students' lack of interest in the use of simulation software or the challenges encountered during the simulation instruction. It could also be due to the poor knowledge of the teacher's technological pedagogical content knowledge to deliver the curriculum contents. When analyzed statistically, the data revealed a significant difference in performance between students taught geometrical transformation using Geometer's Sketchpad simulation software and those taught the same concept using chart-based instruction. This result aligns with the conclusions of Gyedu *et al*. (2020) [6], which demonstrated a significant performance difference between students taught quadratic graphing using a geometrical simulation package and those taught without such simulation. The study's finding also indicated that, within the E.G., male students taught geometrical transformation using Geometer's Sketchpad simulation software outperformed their female peers who were taught the same concept. This was revealed in table 2 where the performance (mean gain = 29.64) of the male students taught with Geometer's sketchpad simulation software was higher than that of the females taught same concept in the same group (mean gain = 28.62). This finding agrees with the research evidences of Abotala (2019) [1] whose findings showed that the male students performed better than the females when taught mathematics with simulation software. Nevertheless, this result contrasts with the findings of Alabi *et al*. (2023) [2], who discovered that female students outperformed male students when simulation software was used to teach and learn kinetic theory. Statistical analysis of this finding revealed no significant difference in performance between male and female students taught geometrical transformations using Geometer's Sketchpad simulation software within the same E.G. This finding agrees with the findings of Alabi *et al*. (2023) [2] which showed that there was no significant difference with respect to gender. The findings of Gamage and Charles-Ogan (2019) [3] also revealed that there was no significant difference with respect to gender.

Conclusion

The findings of this study indicated that employing simulation software like Geometer's Sketchpad significantly enhanced students' performance in mathematics compared to the use of traditional charts.

Recommendations

The recommendations made were as follows

1. Simulation software should be employed to teach mathematics concepts where appropriate.
2. The female students should be encouraged to use technology to learn mathematics concepts.

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