The Impact of Integrating Computer Simulation Package in Flipped Classroom Settings on Students' Mathematics Achievement in Ondo State

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Abstract: This study investigates the effect of computer simulations in an inverted classroom on students' academic performances in Mathematics in the Ondo metropolis of Ondo State. The study adopted a quasi-experimental design with pre-test and post-test control groups. Two public secondary schools with senior school II students, functional computers, and electricity were purposively selected within the Ondo metropolis to participate in the study**.** A total sample of one hundred and ninety-five (195) senior secondary schools II from two public secondary schools in Ondo metropolis participated in the study. Data were collected through the Mathematics Achievement Test (MAT) and computer simulation instructional package (CSIP) developed by the researchers. The statistical package of the social science programme was used for the analysis. The students' pretest and posttest scores were subjected to a sample t-test analysis. The results indicate no significant difference in pre-test scores between the two groups, confirming their equivalence at baseline. However, post-test scores revealed that the experimental group significantly outperformed the control group, demonstrating the effectiveness of the flipped classroom model with computer simulations. Based on the findings of the study, it was recommended that mathematics teachers should adopt a computer simulation package in flipped classroom settings as a student-driven instructional approach capable of sustaining students' interest and improving academic achievement.

Keywords: Computer simulations, inverted classroom, digital tools, academic performances, and active learning.

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Introduction

Technology integration into education has revolutionized traditional teaching methodologies, which has also shown some new learning and teaching breakthroughs in all facets of education. The complexities of the teaching-learning process necessitated the need for teachers and students to embrace the effective integration of digital tools in enhancing classroom activities. These technology interventions are essential and pertinent to mathematical education. Mathematics education is currently witnessing an exponential growth in technology-enhanced learning. A digital learning environment, physical or virtual, provides alternative ways of engaging students in processes that enable better knowledge and understanding of mathematical concepts. Mathematics is the dialect used to portray the issues emerging in many limbs of science and technology. Hence, the subject is enshrined as a fundamental and compulsory subject being offered in Nigerian secondary schools (FRN, 2014).

Over centuries, mathematics has been considered a prime vehicle for developing students' logical thinking and higher-order cognitive skills. Additionally, mathematics also plays a major role in several other scientific fields, such as physics, engineering, and statistics. Avong (2013) referred to mathematics as the foundation for science, without which a nation can never be prosperous and economically independent. He further noted that competence in mathematics provides many of the opportunities for personnel required by industry, science, technology, and education.

Despite the importance of Mathematics to the technological growth of Nigeria, students' performance in Mathematics examinations being conducted by the West African Examinations Council (WAEC), the National Examinations Council (NECO), the National Business and Technical Examinations Board (NABTEB), and the Unified Tertiary Matriculation Examination (UTME) is not encouraging (Oyarinde, 2021, and Avong, 2013). Some of the major reasons for students' poor performances in Mathematics are the abstract nature of the subject, the teacher's personality, a lack of interest, and poor teaching methodology, among others. The situation requires urgent intervention to address the instructional challenges connected with the teaching-learning process of Mathematics at this level of education.

In an attempt to find a viable solution to the challenges of Mathematics at this level, Mathematics teachers need to improve their teaching methods to ensure that students are adequately engaged during the instructional process and to improve student's learning outcomes. The instructional method used by the teachers plays a significant role in the understanding of instructional content for meaningful learning and the development of necessary skills (Olasunkanmi and Oyarinde, 2023). Conventional classroom instructions fall short of providing an immediate learning environment, faster evaluations, and more engagement, which makes students passive with less interaction. In contrast, digital learning tools such as the simulation approach in an inverted classroom setting have the potential to fill this gap in instructional delivery, as they will directly expose the students to the use of technology to engage them in classroom activities.

The inverted classroom approach is an innovative pedagogical approach that focuses on learner-centred instruction and learning where the students are more active than the instructor in the classroom activity (Falode and Mohammed, 2023). In this approach, the instructor acts as a facilitator to motivate, guide, and give feedback on students' performance (Olasunkanmi and Oyarinde, 2023). In the inverted classroom approach to teaching and learning Mathematics, the instructor can move the convectional teaching to video, and the students can listen to the teachings anywhere outside of class. The inverted classroom allows students to watch the video at their preferred time and need, and they can study at their own pace. These types of activities increase students' collaborative learning outside the four walls of classrooms. In this mode, students can explore the mathematical details of the content and sustain curiosity to the highest levels. The carefully structured activities used in flipping the Mathematics class may have enriched the students' Mathematics learning in very specific ways. Studies have shown the importance of an inverted classroom approach to teaching and learning activities.

The study by Salas-Rueda (2022) revealed that the use of an inverted model helped in improving students' performance. Similarly, Oladimeji et al. (2021), in their study established substantial variation in the achievement outcomes of the use of inverted classroom video and audio-visual instructional strategies. In addition, Gambari et al. (2016) discovered that the use of inverted classrooms helped in students' achievement and retention. The study by Adonu et al. (2021) revealed that the use of inverted classrooms boosted the performance of students in terms of achievement and retention. Based on the previous studies, inverted classrooms were effective in classroom activities, but it is still not clear if the same approach will be efficient when a computer simulation is used in an inverted classroom environment.

Computer simulation is a software programme that has a form of graphic imagery in motion that imitates the appearance of physical concepts or phenomena and, when used in a teaching-learning process, may bring about easy conceptualization of concepts taught. The use of technology tools such as computer simulations to teach mathematics allows the students to conceptualise abstract topics, learning at their own pace and gaining mastery of the contents. Computer simulation, according to Inyang (2021), depicts the behaviour or appearance of a system using another channel. Computer simulation provides students with the opportunities of alternative perspectives and worldviews, thereby shaping their intellectual thinking capacity and enhancing their comprehension of theoretical ideas. With computer simulation as an instructional technique, students are exposed to the methods of dealing with matters realistically.

Scholars have noted the usefulness of computer simulation in teaching and learning (Asogwa et al. 2016; Gimba et al. 2015; Ojo 2020;

Ihekoronye et al. 2023). For Asogwa et al. (2016), it increases students' achievement and retention, while Gimba et al. (2015) found that its use in teaching arithmetic and progression improved students' retention. Similarly, Ihekoronye et al. (2023) discovered that students exposed to simulated video and virtual laboratory-based learning performed better in their achievement and problem-solving skills in physics. In addition, Ojo (2020) conducted a study on computer simulation instruction and pupils' achievement in basic science and discovered that pupils exposed to the computer simulation strategy had a higher basic science achievement mean score than their counterparts in the conventional strategy. Show that the computer simulation instructional strategy enhanced primary pupils' achievement in basic science.

Apparently, some factors have been identified as critical parameters that could hinder the use of technology tools in instructional processes. Gender is one of the factors that affects the use of technology in the teaching and learning process. Aderele and Abidoye (2022) described gender as the socially constructed characteristics of women and men, such as norms, roles, and relationships between groups of men (male) and women (female). Debatable among educators is the issue of gender and achievement using technological tools. Adedoja and Fakokunde (2015) reported that gender has no significant effect on students' achievement in computer-based instructional puzzles. In addition, Efuwape and Aremu (2013) revealed that there were no gender differences in the achievement of males and females using computer-based packages. Also, Akinola (2016) revealed similar results in computer programming. The issue of gender is relevant because of the conflicting nature of the results reported by previous studies, which need further investigation, especially at the secondary school level.

However, with the emerging trend in technology-assisted learning, it is observed that not so much has been done to ameliorate the problems of teaching mathematics in secondary schools in Nigeria with the use of technology, particularly computer simulation in flipped classroom settings. It seems the approach has not been extensively utilised in the teaching and learning of mathematics. Thus, there is a need for learner-centred instructional methods that actively engage students in the use of technology for classroom activities. Computer simulation in an inverted classroom has the potential to fill this gap in instructional delivery, as it will directly expose the students to the use of technology to engage them in classroom activities. Therefore, this paper examined the impact of computer simulations in inverted classrooms on students' academic performances in Mathematics in Ondo State, Nigeria.

Objectives of the study

The study examined:

1) The difference(s) in the post-test academic performance of students taught Mathematics using computer simulation in an inverted classroom environment and those taught using the conventional classroom approach.
2) The difference(s) in the post-test academic performance of male and females students taught mathematics using computer simulation in an inverted classroom environment.

Research Questions

1) How does academic performance in Mathematics differ among students taught Mathematics using s computer simulation in an inverted classroom environment and those taught using the conventional classroom approach?
2) To what extent does academic performance in Mathematics differ among males and females students taught Mathematics using computer simulation in an inverted classroom environment?

Hypotheses

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

Ho_1: There is no significant difference between the academic performance of students taught Mathematics using computer simulation in an inverted classroom environment and their counterparts taught with conventional methods.

Ho_2: There is no significant difference between the academic performance of male and female students taught Mathematics using computer simulation in an inverted classroom environment.

Methodology

The study adopted a pre-test, post-test, and control group quasi-experimental research design. Two senior secondary schools were selected to participate in the study within the Ondo Metropolis of Ondo State, Nigeria. One senior secondary school II was purposively selected for the experimental group because they are well-equipped with computer laboratories that are accessible to students; the other was randomly selected for the control group.

Intact classes of one hundred and seventy-five (175) senior secondary schools II made up the study's population. Ninety-three (93) senior secondary schools II were assigned to experimental and eighty-two (82) to control groups. Two research instruments were used to obtain information from the participants: Mathematics Achievement Test (MAT) and computer simulation instructional package (CSIP) developed by the researchers. The reliability coefficient of the instruments was obtained using Cronbach's alpha for MAT, a value of 0.86 and a value of 0.78 was obtained. This was considered to be relatively high enough for the instrument to be used for the study. The completed copies of the questionnaire were collected and analysed using T-test and ANCOVA.

Results

Research Question 1

How does academic performance in Mathematics differ among students taught Mathematics using simulation in an inverted classroom environment and those taught using the conventional classroom approach?

A paired sample t-test was used to answer research questions 1 and 2, and the results are presented in Tables 1 to 3.

Table 1: Differences between the experimental and control groups before the intervention

Group	N	X	SD	T	DF	Sig.	Remark
Experimental	93	45.2	10.3				
				0.29	198	0.77	Not Significant
Control	82	44.8	10.7				

Significant at 0.05 alpha levels

Table 1, shows that there was no statistically significant difference between the pre-test scores of the experimental group ($\bar{x} = 45.2$, N= 93, SD= 10.3) and control group ($\bar{x}$ = 44.8, N= 82, SD=10.7) and (T= 0.29, sig = 0.77 and $p < 0.05$) before they were exposed to intervention. In other words, before the intervention, both groups of students exhibited the same levels of problem-solving skills and were equivalent in terms of initial Mathematics achievement.

Table 2: Differences between the experimental and control groups after the intervention

Group	N	X	SD	T	Df	Sig.	Remark
Experimental	93	78.5	8.6				
Significant				6.92	198	.00*	
Control	82	68.9	9.4				

Significant at 0.05 alpha levels

The result from table 2 reveals a significant difference in the post-test scores of the experimental group after being exposed to the intervention ($\bar{x}$ = 78.5, N= 93, SD= 8.6) and the control group ($\bar{x}$ = 68.9, N= 82, SD =9.4), and (T= 6.92, sig = 0.001and $p < 0.05$). This indicates that students in the inverted classroom with computer simulations performed significantly better than their peers in the traditional classroom setting.

Research Question 2

To what extent does academic performance in Mathematics differ among males and females students taught Mathematics using computer simulation in an inverted classroom environment?

Table 3: Differences between the achievement scores of male and students after the intervention

Group	N	X	SD	T	Df	Sig.	Remark
Male	65	48.7	10.8				
Significant				0.84	198	0.399	Not
Female	110	49.2	11.2				

Significant at 0.05 alpha levels

Table 3 shows that there was no statistically significant difference between the academic performance of male and female students after the intervention. Male ($\bar{x} = 48.7$, N= 65, SD= 10.8) and Female ($\bar{x} =$ 49.2, N= 110, SD=11.2). This shows that the instructional package will be of immense benefit to all students, regardless of their gender disparity (T= 0.84, sig = 0.399 and p < 0.05). The values of the mean scores do not reveal an appreciable difference.

$H0_1$: There is no significant difference between the academic performance of students taught Mathematics using computer simulation in an inverted classroom environment and their counterparts taught with conventional methods.

ANCOVA was used to test null hypotheses 1 to 3 (**Ho_1 to Ho_3**) and the results are presented in the table below.

Table 4: Analysis of Covariance (ANCOVA) of Post-Achievement by Treatment and Gender

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	4596.932[a]	4	1149.233	507.620	.000	.933
Intercept	888.775	1	888.775	392.575	.000	.729
Pre-Achievement	4517.686	1	4517.686	1995.478	.000	.932
Treatment	1433.065	1	1433.065	632.990	.000*	.813
Gender	.615	1	0.615	.272	.603	.002
Treatment x Gender	1.074	1	1.074	.474	.492	.003
Error	330.538	170	2.264			
Total	41004.000	175				
Corrected Total	4927.470	174				

*R Squared = .933 (Adjusted R Squared = .931), *p<.05*

Table 4 showed that there was a significant main effect of treatment on students' academic performance in Mathematics. ($F_{(1,170)} = 632.99$; $p<0.05$, partial η2 = 0.81). The effect is 81.0%. This indicated that there was a significant difference in the students' post-academic performance in Mathematics. Thus, hypothesis 1 was rejected. To determine the magnitude of the significant main effect across treatment groups, the estimated marginal means of the treatment groups was carried out and the result is presented in table 5.

Table 5. Estimated marginal means for post-academic performance by treatment and control group

Treatment	Mean	Std. Error
Computer simulation	19.60	.21
Conventional Method	12.13	.18

Table 5 indicated that in Computer Simulation (CSS) treatment group had the higher adjusted post-achievement mean score in basic science (=19.60), while the Conventional Method (CM) control group had the least adjusted post-achievement mean score (= 12.13). This order can be represented as CS > CM.

Ho2: There is no significant difference between the academic performance of male and female students taught Mathematics using computer simulation in an inverted classroom environment.

Table 5 showed that there was no significant main effect of gender on students' academic performance in Mathematics ($F_{(1,170)} = 0.27$ $p>.05$).

Therefore, hypothesis 2 was not rejected. This implies that gender did not affect students' academic performance in Mathematics.

Discussion of Findings

The results obtained from Hypothesis 1 reveal that there is a significant difference in the academic performance of the students taught with the computer simulation in an inverted classroom environment and their counterparts taught with the conventional method of teaching. This implied that the computer simulation in an inverted classroom had a significant influence on student's academic performances in Mathematics. In other words, this approach allows students to study at their own pace, promotes active learning, and makes the learning contents more available to them anytime, anywhere. Also, it allows students to spend more time on assigned tasks, and they are able to prepare and study the learning contents several times before the classroom time. This finding agrees with Falode and Mohammed (2023), who observed that computer simulation packages in an inverted classroom environment stimulate students’ curiosity, engagement, and enlightenment. The study by Ojo (2020) shows that computer simulation packages contributed to students’ academic success in basic science, and the study by Ihekoronye, Akinyemi, and Aremu (2023) revealed similar results in physics.

The results of the analyses obtained from Hypothesis 2 showed that there was no statistically significant difference between the achievement scores of male and female students after the intervention. This implied that both male and female participants benefited equally from the learning package. This is to show that the instructional package will be of immense benefit to all students, regardless of gender disparity. This finding aligns with the observation of Abidoye (2023), who reported no significant difference between the academic performance of male and female students taught with a flipped classroom instructional package. The results were in line with the findings of Elian and Hamaidi (2018), who revealed that there are no differences in male and female academic performance when taught with a mobile phone instructional package. This shows that students, whether males or females, benefit equally from using technological tools because of their availability and accessibility.

Conclusion

The findings of the study revealed that the inverted classroom model, when combined with computer simulations, is more effective in improving students' academic performances in Mathematics than traditional classroom instruction. The results show that computer simulations provide an interactive and engaging way for students to understand complex mathematical concepts, leading to better performance. Also, the active learning environment created by the inverted classroom model contributes to deeper understanding and retention of mathematical concepts. The results revealed there is no significant gender implication; the interventions benefit both male and female students equally.

Recommendations

Based on the study's conclusions, the following recommendations are proposed:

i. Educators should consider incorporating inverted classroom models with computer simulations to enhance student engagement and achievement.
ii. Periodic training and seminars should be organised for Mathematics teachers to use computer simulations and manage inverted classroom environments.
iii. The government should develop policies that encourage and support the use of innovative teaching methods, including inverted classrooms and technology-enhanced learning.
iv. The government, through the educational resource centres, should allocate funding and resources to support the implementation of technology-enhanced learning environments in schools.

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