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Blended Learning for Enhancing Mathematics Retention and Conceptual Understanding: Implications for STEM Teachers

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The study aimed to evaluate the impact of blended learning on mathematics retention among secondary school students. Conducted in the Isoko North Local Government Area of Delta State, Nigeria, the research involved 1,235 senior class one (SS 1) students. Employing a non-equivalent control group pre-test-post-test quasi-experimental design, a sample of 70 students was selected from two secondary schools with ICT facilities through purposive sampling. Random allocation of students into experimental and control groups was achieved through balloting within each selected school. The investigation included three assessment points: pre-Mathematics Achievement Test (MAT), post-MAT, and post-post-MAT (retention), administered systematically by the researchers. Data collection utilized the established MAT instrument, which demonstrated a high reliability score of 0.86. Statistical analysis was conducted using the Statistical Package for Social Sciences (SPSS) version 28, with mean and standard deviation addressing study questions and analysis of covariance scrutinizing hypotheses at a significance level of .05. Results revealed significantly greater improvements in mathematics retention scores among students exposed to blended learning compared to those instructed through conventional methods. Moreover, noticeable differences in mean retention scores were observed, with male students in the blended learning group exhibiting notably higher performance. Based on these findings, recommendations were made, advocating for mathematics educators to integrate blended learning, particularly in geometry teaching, to enhance students' retention of mathematical concepts.

Keywords: blended learning, flipped classroom model, secondary school students, station rotation model.

1. Introduction

Mathematics education is a critical component of secondary school curricula, serving as a

foundation for various academic and professional pursuits [1]–[4]. Retaining mathematical concepts among secondary school students is paramount for their academic success and future career opportunities [5], [6]. However, the persistent challenge of low mathematics retention rates highlights the need for innovative approaches to teaching and learning [7]. The variables influencing secondary school mathematics retention are multifaceted, encompassing pedagogical and environmental factors. Among these variables are the teaching methods employed, the students' engagement levels and the learning environment provided [5], [7], [8]. Traditional teaching methods often fall short of fostering a deep understanding of mathematical concepts, leading to lower retention rates among students [6], [9]–[11]. The inadequacy of conventional teaching approaches necessitates a reevaluation of the educational methods employed in secondary schools [7], [12]–[15].

The problem at hand is the suboptimal mathematics retention rates among secondary school students, which can be attributed to a combination of factors. Insufficiently effective teaching methods, coupled with a lack of student engagement, contribute to a surface-level understanding of mathematical concepts [9], [13], [23], [24], [14], [16]–[22]. The result is a disconnect between theoretical knowledge and practical application, hindering students from retaining and applying mathematical principles beyond the classroom [9]. In addressing this problem, an innovative and promising method is the integration of blended learning into the mathematics curriculum [25]–[27].

Blended learning combines traditional face-to-face instruction with online resources and interactive activities, offering a holistic approach to teaching and learning [28], [29]. The integration of technology provides students with a dynamic and interactive learning environment, catering to diverse learning styles and enhancing their overall understanding of mathematical concepts [30]. The choice to explore blended learning as a solution is grounded in the recognition of the limitations of conventional teaching methods. Traditional approaches often focus on rote memorization and procedural understanding, neglecting the need for a deeper conceptual grasp [18]. Blended learning, with its incorporation of digital tools, allows for a more personalized and adaptive learning experience, fostering a comprehensive understanding of mathematical concepts [31]. There are four types of blended learning models, according to [32]. The models under consideration here include rotation, flex, self-blend, and enriched-virtual models. Among them, this research focuses on the Rotation model, specifically exploring station rotation and flipped-classroom models. The Rotation Model comprises four sub-models: Station Rotation Model, Lab Rotation Model, Flipped-Classroom Model, and Individual Rotation Model [32].

Diverse studies have delved into the effectiveness of blended learning in boosting academic achievement and retention in science education across a range of contexts. For instance, in India, researchers [30] examined the impact of blended learning on physics achievement and retention among higher secondary learners. Employing a quasi-experimental design with 40 students and utilizing the t-test, they noted significant enhancements in physics performance and retention among the experimental group compared to the control. Interestingly, both male and female students demonstrated equal achievement and retention in physics concepts through blended learning. Similarly, in Niger State, Nigeria, [28] investigated the effectiveness of computer-based blended learning in enhancing chemistry retention among secondary school students. Employing ANCOVA with a sample of 120 students, their findings showcased the

efficacy of blended learning in improving chemistry retention. Expanding to higher education, a study in Abuja, Nigeria [29], explored the effectiveness of blended learning models in science education courses at the university level. Utilizing a quasi-experimental design with 120 students and employing the t-test, they observed improved science achievement and retention in the experimental group compared to the control.

The literature review offers valuable information on how blended learning can improve academic performance and retention in science education at different levels and locations. However, there is a notable gap in research as no studies have focused on the impact of blended learning on the retention of math knowledge among secondary school students, including both boys and girls. While studies by [30], [28], and [29] have explored the impact of blended learning on physics and chemistry retention at higher secondary and university levels, none have focused on mathematics retention among secondary school students in the reviewed literature. This significant lack of research emphasizes the necessity for a study that focuses on how blended learning can improve mathematics retention, taking into account the specific difficulties and complexities related to this subject. Moreover, the absence of research focusing on gender differences in mathematics retention further underscores the significance of this gap. The current study seeks to fill this void in the literature by conducting a quasi-experimental investigation into the effectiveness of blended learning on secondary school students' mathematics (geometry) retention, paying particular attention to potential gender variations. Specifically, the research questions are as follows: (1) What are the retention scores of learners who received mathematics instruction through the blended learning approach compared to those in the control group? (2) What are the retention scores of male and female learners who received mathematics instruction through the blended learning approach compared to those in the control group? The formulated hypotheses are as follows: (1) There is no statistically significant difference in retention scores between learners who received mathematics instruction through blended learning and those in the control group. (2) There is no statistically significant difference in retention scores between male and female learners who received mathematics instruction through the blended learning approach compared to those in the control group.

2. Theoretical Framework

This study is informed by Cognitive Load Theory (CLT) and Social Constructivism. Cognitive Load Theory (CLT), proposed by Sweller (1988), posits that learners have a limited capacity for processing information, and cognitive overload can hinder learning. Blended learning helps manage cognitive load by providing various instructional formats, such as video lectures, quizzes, and interactive tasks, which reduce mental strain and allow students to engage with mathematical concepts in multiple ways. This flexibility facilitates the consolidation of knowledge and promotes long-term retention. In the context of this study, CLT explains how blended learning environments can enhance students' retention of mathematics by ensuring that content is delivered in ways that avoid cognitive overload and support more efficient learning.

In addition to CLT, Social Constructivism, as articulated by Vygotsky (1978), underscores the importance of social interaction in the learning process. Vygotsky’s concept of the Zone of

Proximal Development (ZPD) emphasizes that learners achieve optimal growth when they interact with more knowledgeable peers or instructors, which helps them reach higher levels of understanding. Blended learning supports this by facilitating both face-to-face and online interactions, allowing students to collaborate, problem-solve, and engage with mathematical content in a social context. For this study, Social Constructivism provides a framework for understanding how the social aspects of blended learning, such as peer discussions and teacher guidance, contribute to deeper mathematical understanding and improved retention.

By drawing on these two theories, this study seeks to explore how blended learning can affect students' retention of mathematical concepts, particularly in geometry. Cognitive Load Theory helps explain how blended learning environments reduce cognitive load, making it easier for students to retain mathematical knowledge. Meanwhile, Social Constructivism emphasizes the role of social interactions in learning, which can enhance retention by promoting collaborative and guided learning experiences.

3. Methodology

In this study, a quasi-experimental design with a non-equivalent control group was employed to examine the impact of blended learning on the retention of mathematics among senior class one (SS 1) students in the Isoko North Local Government Area of Delta State, Nigeria. The population of the study comprises 1,235 SS1 students. A sample of 70 students was selected using a combination of purposive sampling and random assignment. Firstly, two secondary schools were purposively selected from the nineteen schools in the area based on their ICT facilities, as reported by the Post Primary Education Board, Oleh Zonal Office, in 2023. Within each selected school, students from intact SS1 classes formed the sample for the study. These intact classes were then randomly assigned to either the experimental or control group by balloting, ensuring that any observed differences could be attributed to the experimental intervention rather than pre-existing differences.

The research employed the Mathematics Achievement Test (MAT) as the primary tool for data collection. Furthermore, separate lesson plans were meticulously crafted for both the experimental and control groups. Data collection involved administering the MAT to both groups, comprising 20 multiple-choice questions strategically aligned with a comprehensive test blueprint covering various mathematical concepts. The researchers meticulously developed lesson plans for the treatment groups, which underwent rigorous review by experts in Mathematics Education and Measurement and Evaluation. To assess the reliability of the MAT, it was administered to 40 SS 1 students from a school located outside the local government area under study. The internal consistency of the MAT was evaluated using the Kuder-Richardson formula 20, yielding a commendable value of 0.86 calculated with SPSS software version 28.

This study received official approval from the principals of the two selected schools. Verbal consent from SS2 students was secured before the research commenced. The math teachers from selected schools were involved as research assistants and underwent a week of training on utilizing blended learning techniques to teach Geometry (Circle theorem). They were provided with lesson plans/notes, with the experimental group following the blended learning approach and the control group using traditional methods.

The Experimental Group underwent a four-week blended learning treatment guided by mathematics teachers. In-class sessions featured a station rotation method encompassing face-to-face instruction, small group discussions, and online learning. The students actively engaged in after-class activities, including video lectures, readings, quizzes, and assigned tasks related to the circle theorem. This approach aimed to integrate traditional teaching with online elements to enhance learning outcomes. Meanwhile, the Control Group received traditional teaching methods guided by mathematics teachers over the same four-week period. In-class sessions involved explanations of the circle theorem using flashcards and activity worksheets, with homework assignments distributed and collected for assessment. Additionally, the application of the theorems was taught through examples, fostering student questions and discussions. After-class activities focused on independent completion of assigned tasks and homework related to the circle theorems.

To systematically assess learning outcomes, the study involved three assessment points: pre-Mathematics Achievement Test (MAT), post-MAT, and post-post-MAT (retention), systematically administered by the researchers. In the pre-test phase, both experimental and control groups underwent the MAT to establish baseline measurements. Subsequently, the experimental group received the blended learning intervention, while the control group adhered to the conventional instructional approach. Following the four-week intervention, a post-test (post-MAT) was administered to both groups in the fifth week to evaluate immediate learning outcomes. Additionally, a retention test (post-post-MAT) was conducted four weeks after the post-test to assess the long-term impact of blended learning. The gathered data were analyzed using SPSS, with study questions addressed through mean and standard deviation analysis, while hypotheses were tested using analysis of covariance (ANCOVA) at a significance level of 0.05.

4. Result

The results are presented according to the research questions and hypotheses that guided the study.

Research Question 1: What are the retention scores of learners who received mathematics instruction through the blended learning approach compared to those in the control group?

Table 1. Posttest and retention mean scores for students' mathematics retention in both groups

Group	N	Posttest		Retention		Mean Difference
		M	SD	M	SD	
Blended learning approach	38	79.7	17.1	73.6	18.8	6.1
Conventional approach	32	63.1	10.4	45.7	18.3	17.4

Note. N = Number of Respondents, M = Mean, SD = Standard deviation

Table 1 shows the retention scores of both the experimental and control groups. In the blended learning group, students had an average posttest score of 79.7 (standard deviation = 17.1) and

an average retention score of 73.6 (standard deviation = 18.8), resulting in a mean difference of 6.1. Conversely, the conventional group had an average posttest score of 63.1 (standard deviation = 10.4) and an average retention score of 45.7 (standard deviation = 18.3), with a mean difference of 17.4. As a result, students in the blended learning group showed higher average retention scores compared to their peers in the control group.

Hypothesis 1: There is no statistically significant difference in retention scores between learners who received mathematics instruction through blended learning and those in the control group.

Table 2. Analysis of covariance of the variation in students' trigonometry retention scores

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Decision
Corrected Model	18758.402[a]	4	4689.601	16.641	.000	.506	
Intercept	1814.609	1	1814.609	6.439	.014	.090	
PostTAT	2481.915	1	2481.915	8.807	.004	.119	
Group	4724.423	1	4724.423	16.764	.000	.205	Sig
Gender	418.602	1	418.602	1.485	.227	.022	Sig
Group*Gender	1161.178	1	1161.178	4.120	.046	.060	
Error	18318.184	65	281.818				
Total	295963.000	70					
Corrected Total	37076.586	69					

a. R Squared = .506 (Adjusted R Squared = .476). Note. df= Degree of Freedom, F= F-ratio, Sig.= Significant

Table 2 displays the outcomes of the ANCOVA analysis, which investigated the difference in retention scores between students in the experimental group exposed to blended learning and those in the control group who received traditional instruction. The results revealed a significant main effect for treatment groups, with $F(1, 65) = 7.353$, $p = .000$. Since the p-value (.000) is lower than the predetermined significance level of $p<.05$, we reject the null hypothesis indicating no significant difference. Thus, we infer that student in the experimental group retained mathematical concepts significantly better than those in the control group. Additionally, the analysis revealed a partial eta squared effect size of .205, indicating that 20.5% of the variation in students' retention scores can be attributed to the blended learning approach alone.

Research Question 2: What are the retention scores of male and female learners who received mathematics instruction through the blended learning approach compared to those in the control group?

Table 3. Retention means scores of male and female students in both groups

Group	Gender	N	Posttest		Retention		Mean Difference
			M	SD	M	SD	
Blended approach	Male	21	83.1	11.7	81.1	11.1	2
	Female	17	75.5	21.7	64.2	22.3	11.3

Conventional approach	Male	18	68.4	7.2	46.7	18.7	21.7
	Female	14	56.2	9.9	44.3	18.3	11.9

Note. N = Number of Respondents, M = Mean, SD = Standard deviation

Table 3 illustrates the mean retention scores categorized by gender in both the experimental and control groups. In the blended learning group, male students had a mean posttest score of 83.1 (SD = 11.7) and a mean retention score of 81.1 (SD = 11.1), showing a difference of 2 in means. Conversely, female students had an average posttest score of 75.5 (SD = 21.7) but experienced a decrease in retention to 64.2 (SD = 22.3), resulting in a notable difference of 11.3 between genders. This data indicates that male students in the blended learning group retained geometry concepts better than their female counterparts. In the conventional approach group, male students achieved an average posttest score of 68.4 (SD = 7.2) and a retention score of 46.7 (SD = 18.7), resulting in a substantial difference of 21.7 in means. In contrast, female students in this group obtained an average posttest rating of 56.2 (SD = 9.9) and a retention score of 44.3 (SD = 18.3), leading to a mean difference of 11.9 between genders. Similar to the findings of the blended learning approach, male students in the conventional approach group exhibited higher mean retention scores than their female counterparts.

Hypothesis 2: There is no statistically significant difference in retention scores between male and female learners who received mathematics instruction through the blended learning approach compared to those in the control group.

Hypothesis 2 was assessed in relation to the ANCOVA findings presented in Table 2. The analysis of the discrepancy in achievement scores between male and female students in both the experimental and control groups showed a lack of significant gender effect ($F(1, 65) = .227$, $p = .022$), leading to the retention of the null hypothesis. However, a notable interaction effect between Gender and Group was identified ($F(1, 65) = 4.120$, $p = .046$), indicating that the connection between gender and math retention scores varies across different instructional groups. While there may not be an overall difference in retention scores between male and female students, the significant interaction effect emphasizes the importance of considering instructional group distinctions when examining the complex relationship between gender and mathematics achievement outcomes. Further analysis revealed that male students had significantly higher mean retention differences within the blended learning group compared to female students (refer to Table 3), contributing to the observed interaction effect. Therefore, it can be concluded that there are significant differences in retention scores between male and female students who received math instruction using the blended learning method.

5. Discussion

The results of this research provide strong evidence that the use of a blended learning method significantly improves students' ability to retain mathematical concepts, particularly compared to traditional teaching methods. This positive impact aligns with existing research by [30], [29], and [28], which collectively highlight the robust contribution of blended learning to improved retention in science-related subjects. According to Cognitive Load Theory (Sweller, 1988), blended learning reduces cognitive overload by presenting information through diverse formats, such as video lectures and interactive tasks, which help students engage with material

at their own pace and revisit challenging concepts. This flexibility appears to enhance the retention of mathematical concepts, especially in geometry, by providing an environment where students can manage their cognitive load effectively. The consistency of these positive results across different geographical and educational contexts further underscores the broad applicability and effectiveness of blended learning strategies.

Additionally, the analysis focusing on gender differences revealed that both male and female students in the experimental group exhibited improved retention in mathematics compared to their peers in the control group. However, a deeper examination prompted by hypothesis two revealed a notable difference in retention scores between male and female students, with males demonstrating higher average retention scores when instructed through the blended learning approach. This finding deviates from previous research, such as that by [30], who reported equal retention for both genders in the context of physics. The discrepancy observed in this study may be attributed to several factors, including instructional design, content delivery, and cultural context, all of which are influenced by the Social Constructivist approach (Vygotsky, 1978). According to this theory, the social interactions within the learning environment, such as peer discussions and teacher guidance, play a crucial role in shaping students' learning experiences. Gender differences in retention could be influenced by how male and female students interact with the learning materials and with each other during the blended learning process. Moreover, cultural context and potential biases in instructional methods may also contribute to the observed differences.

6. Conclusions

The implementation of blended learning significantly improved students' mathematical retention, as evidenced by higher average scores in the experimental group compared to the control group. A gender disparity was observed, with male students benefiting more from blended learning in terms of retention scores. This finding contributes to the existing literature and highlights the effectiveness of blended learning, particularly for male learners in mathematics. The study is groundbreaking as it examines the impact of blended learning on mathematics retention in Isoko North LGA and emphasizes gender differences in retention, favouring males.

Despite these promising results, this study has certain limitations that should be acknowledged. The novelty effect associated with blended learning may have temporarily boosted student engagement, necessitating further research on the long-term sustainability of its impact. Additionally, the sampling technique used—focusing on schools with specific technological facilities—may limit the generalizability of the findings. Future studies should adopt broader and more diverse sampling methods to ensure applicability across different educational contexts. Another limitation is the lack of consideration for teacher-related factors, such as pedagogical expertise, years of experience, and familiarity with blended learning strategies, which may have influenced student retention outcomes. Addressing these variables in future research will provide deeper insights into how teaching approaches influence student learning and retention in mathematics.

Implications for STEM Teachers

The findings of this study have important implications for STEM teachers, particularly in mathematics education. Given the demonstrated effectiveness of blended learning in enhancing mathematics retention, teachers should consider incorporating this approach into their instructional methods. By combining traditional face-to-face instruction with digital resources, educators can create a more interactive and student-centered learning environment that promotes deeper understanding and long-term retention of mathematical concepts.

However, successful implementation requires proper training and professional development. Many teachers may not have the necessary skills to design and facilitate blended learning effectively. Therefore, professional development programs should focus on equipping educators with digital pedagogy, online content creation, and interactive learning strategies to maximize the potential of blended learning.

Additionally, the observed gender disparity in retention outcomes highlights the need for inclusive instructional strategies. While male students in this study demonstrated higher retention scores, it is essential for teachers to ensure that blended learning environments are equitable and supportive of all learners, regardless of gender. This may involve adopting differentiated instructional techniques that cater to diverse learning preferences, such as incorporating adaptive learning tools, collaborative assignments, and varied assessment methods.

To ensure the sustainability of blended learning, schools should consider gradually integrating its core elements into the mathematics curriculum. Establishing professional learning communities among STEM teachers can facilitate knowledge-sharing and allow educators to refine their approaches based on best practices. By embracing blended learning as a pedagogical tool, STEM teachers can significantly enhance students' retention and conceptual understanding in mathematics, ultimately contributing to improved performance in STEM-related subjects.

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