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Collaborative learning in flipped classrooms: enhancing physics education retention in Nigerian secondary schools

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Abstract

The study examined the impact of three flipped modes of classroom collaborative learning strategies on secondary school students' retention in Physics in Minna by employing a quasi-experimental design. A sample of 146 students (67 male and 79 female) from four randomly selected Senior Secondary Schools participated. The study formulated three research questions and corresponding hypotheses, tested at a 0.05 significance level. A validated 50-item multiple-choice Physics Achievement Test (PAT) with a reliability coefficient of 0.84 was used for data collection. ANCOVA was employed to analyse the hypotheses. Results indicated that flipped classroom approaches significantly affected students' achievement and retention. Both male and female students benefited equally from these strategies. The study recommends implementing flipped classroom techniques to enhance Physics instruction in Nigeria, along with training workshops for teachers on blended learning methods.on blended learning methods.

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Flipped classroom, collaborative learning, Physics education, student retention, quasi-experimental design, blended learning

INTRODUCTION

Integrating technology into everyday life should also influence how students are taught in today's classrooms. Nigeria recognised the importance of technology, which was emphasized in the National Policy on Education that a more significant proportion of educational expenditure will be devoted to science and technology (Federal Republic of Nigeria (FRN), 2013). There is a direct proportional relationship between the level of development of a society and the level of technological advancement. Developed countries are societies with high levels of technological advancement (Jegede & Adebayo, 2013).

The application of technology in the instructional process spans various disciplines, including science. Science teaching in Nigerian secondary schools began with the establishment of grammar schools in 1859. At that time, Physics was one of the science subjects taught at the secondary school level in Nigeria. Physics is the study of matter, energy, and their interactions. It plays a key role in the progress of mankind (Omebe, 2009). Physics education is a crucial factor in national development. The Nigerian education scheme for secondary school Physics, introduced in 1985, outlines objectives that include, among others, providing basic literacy in Physics for functional living in society and equipping students with essential scientific skills and attitudes as a foundation for the technological application of Physics (Jegede & Adebayo, 2013).A country's development, including Nigeria's, depends on its ability to acquire and utilise innovation, which cannot be achieved without adequate knowledge of physics.

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Many essential technologies, such as light bulbs, digital cameras, cars, cell phones, aeroplanes, solar panels, fibre optics, DVD players, computers, MP3 players, grocery scanners, flat-screen televisions, and even space rockets, owe their existence to the principles of physics. Therefore, it can be argued that such innovations would be impossible without physics. Mulvey and Pold (2015) reported that physics helps individuals develop critical thinking and problem-solving skills. These contributions to physics play a significant role in improving humanity's well-being. Given the numerous benefits of this subject, greater attention should be paid to the teaching of physics, especially at the secondary school level. Research findings indicate that students' performance in Physics has been consistently low in internal and external examinations in Nigeria (Aiyelabegan, 2003; Akanbi, 2003; Kola, 2007; & Bello, 2012).

The traditional teaching methods have primarily revolved around a teacher-centred approach where instructors focus on conveying information, assigning work, and leaving it to the students to master the material. This type of instruction forces students to be mere receptors of information rather than participants in their learning processes through active learning. To overcome these problems, there is a need for a paradigm shift from traditional teaching methods to innovative teaching strategies using modern technological devices. Fortunately, technology has increasingly grown and infiltrated the classrooms, especially in developed countries; new learning models have emerged that move away from the teacher-centred approach to a more collaborative (student-centred) learning environment. These include mobile learning, collaborative learning, web-based learning, and flipped classrooms (UNESCO, 2016).

Flipped classroom instruction (Flipped Learning Network, FLN, 2014) is a pedagogical approach in which direct instruction shifts from group learning to individual learning, while classroom time is transformed into a dynamic, interactive environment. In this model, the teacher acts as a facilitator, guiding students as they apply concepts and engage creatively with the subject matter. In practice, activities often involve students preparing for lessons by watching pre-recorded lectures or completing assigned readings and tasks. Class time is used for interactive discussions, problem-solving, and other collaborative activities. Consequently, the teacher moves from being the 'sage on the stage' to the 'guide on the side' (Federal Learning Network, 2014).

One of the underlying aims of flipped classroom instruction is to promote deeper learning and improve long-term understanding, key factors in student retention. Retention, the ability to recall learned concepts when needed (Seidman, 2012), is vital for academic success, particularly in subjects requiring critical thinking and problem-solving. It is more likely to occur when content is meaningfully encoded into memory, which can be enhanced by engaging and student-centred teaching approaches such as the flipped classroom. Moreover, appropriate use of instructional media, including e-learning tools, has been shown to stimulate interest and improve retention outcomes.

However, empirical studies on student retention and the influence of gender in Physics have produced conflicting and inconclusive findings. Some scholars, such as Danmole (1998) contend that male students outperform their female counterparts in science subjects such as Physics. In contrast, studies by Atadoga, Zaria, Mari, and Danjuma (2016) report that female students demonstrate superior performance. Meanwhile, researchers, including Kirkpatrick and Cuban (1998) and Yusuf and Afolabi (2010), have found no significant gender-based differences in retention when both male and female students are provided with equivalent learning experiences, indicating that retention outcomes may be comparable across genders.

Moreover, research suggests that teacher-centred instructional methods, in which learners play a largely passive role, have a detrimental effect on retention, particularly in science disciplines that demand higher-order thinking skills such as evaluation, analysis, and creative application. Blended learning approaches like the flipped classroom model have shown greater efficacy than conventional teaching strategies (Akiri & Ugborugbo, 2009; Ayodele & Adebiyi, 2013; Okoro, 2004). However, there remains a paucity of research examining the specific flipped classroom

collaborative learning strategies that significantly enhance student achievement and retention, particularly within the Nigerian educational context. This study, therefore, seeks to address this gap by investigating the effects of such strategies on the retention of Physics concepts among secondary school students in Minna, Nigeria.

Furthermore, studies on implementing flipped classrooms in Physics within Nigerian secondary schools remain limited. Research exploring the integration of flipped classrooms with collaborative learning strategies is also still emerging in developing countries. To address this gap, the present study investigates the effects of three well-established flipped classroom collaborative learning strategies, adapted from existing literature: (1) Reciprocal Teaching (RT), (2) Think-Aloud Paired Problem Solving (TAPPS), and (3) Think-Pair-Share (TPS) (Barkley, Cross, & Major, 2005).

Reciprocal Teaching (RT) involves students and teachers alternating roles as discussion leaders, employing techniques such as predicting, questioning, clarifying, and summarising (McAllum, 2014). TAPPS pairs students, one verbalising their thought processes while solving a problem and the other offering prompts and feedback, enhancing problem-solving skills and metacognitive awareness. TPS encourages critical thinking through a structured process in which students first reflect individually (THINK), then discuss their ideas with a partner (PAIR), and finally share their conclusions with the wider class (SHARE), thereby fostering collaboration and more profound understanding (Rowe, 1972; Johnson & Johnson, 1999).

Based on the previous discussion, this study will determine the most effective flipped collaborative strategy for teaching secondary school subjects, particularly Physics, by comparing different approaches. Research has shown that Physics is often challenging for students (Akiri & Ugborugbo, 2009; Ayodele & Adebiyi, 2013; Okoro, 2004), highlighting the need for innovative teaching methods to improve retention. While most studies on flipped classroom collaboration have been conducted in tertiary institutions, research in secondary schools remains limited. Therefore, this study will significantly contribute to the current discourse on implementing the flipped classroom and its impact on student retention.

This study will answer three research questions as follows: (1) What is the difference in the mean achievement scores of students taught Physics using flipped classrooms in collaborative learning settings—reciprocal teaching (RT), think-aloud paired problem-solving (TAPPS), and think-pair-share (TPS)—compared to those taught using individualised learning (IL)? (2) What is the difference in the mean retention scores of students taught Physics using these flipped classroom collaborative strategies versus those taught using IL? (3) What is the difference in the mean retention scores between male and female students taught Physics using flipped classroom collaborative strategies (RT, TAPPS, and TPS) and those taught using IL?

Three hypothetical statements will be tested to support these research questions.

Ho_1: There is no significant difference in the mean achievement scores of students exposed to the flipped classroom in collaborative learning settings (reciprocal teaching (RT), think-aloud paired problem-solving (TAPPS), and think-pair-share (TPS)) and those taught using individualised learning settings.

Ho_2: There is no significant difference in the mean retention scores of students exposed to the flipped classroom in collaborative learning settings (reciprocal teaching (RT), think-aloud paired problem-solving (TAPPS), and think-pair-share (TPS)) and those taught using individualised learning settings.

Ho_3: There is no significant difference in the mean retention scores of male and female students taught Physics using flipped classrooms in collaborative learning settings (reciprocal teaching (RT), think–aloud paired problem-solving (TAPPS), and think pair share (TPS)) and those taught using individualised learning (IL) setting

METHOD

A. Research design

The research design employed for this study is a quasi-experimental design including a pre-test, post-test, non-equivalent, and control group design (Stevenson, 2020). It involves four levels of independent variables (three treatments – three collaborative learning strategies and a control – individualised learning strategy), two levels of dependent variables (achievement and retention), and a moderating variable of gender (male and female). All the experimental and control groups were pre-tested and post-tested, and a retention test was conducted thereafter. The four participating schools were assigned to Think Pair Share (TPS), Think Aloud Pair Problem Solving (TAPPS), Reciprocal Teaching (RT), and Individualised Learning (IL), respectively. The design layout is shown in Table 1

Table 1 Research design layout

Groups	Pre-test	Treatment	Post-test	Retention test
Exp Group 1	O_1	X_1	O_2	O_3
Exp Group 2	O_1	X_1	O_2	O_3
Exp Group 3	O_1	X_1	O_2	O_3
Control Group	O_1	X_1	O_2	O_3

Where,
O1 = Pre-test for all the groups.
O2 = Post-test for all the groups.
O3 = Retention test for all the groups.
X1, X2, X3 = Treatment for experimental group one (RT), two (TAPPS), and three (TPS))
Xo = Treatment for the control group (IL)

B. Population of the study

The population of this study comprised all 27,621 senior secondary school students in Minna Metropolis, Niger State. The target population included all 11,663 Senior Secondary II (SSII) Science students in Minna Metropolis, Niger State, as of the 2018/2019 academic session (Education Resource Center, Minna, Niger State). The sample study comprised 146 science students in Minna from four Senior Secondary II (SSII) schools. Table 2 presents a summary of the sample schools.

Table 2 The summary of the sampled schools

S/N4	Name of School	Male	Female	Total
1	School A	21	21	42
2	School B	17	28	45
3	School C	21	22	43
4	School D	8	8	16
	Total	67	79	146

Three sampling techniques were employed in this study. Firstly, a purposive sampling procedure was adopted to select four senior secondary schools in Minna, Niger State. The schools were selected based on the following criteria: (i) gender consideration (co-educational schools), (ii) school that offers Physics as a subject, and (iii) schools that have computers/computer laboratories. Secondly, the selected four equivalent co-educational schools were randomly assigned to each of the three experimental and a control group using a simple random sampling technique. Thirdly, a stream of classes was randomly selected from each school. An intact class was used in this study.

Two research instruments were used in this study: (i) Flipped-classroom instructional package (FIP) and (ii) Physics Achievement Test (PAT). The researchers and video producer developed the FIP for teaching Physics at senior secondary school class II (SSSII), which is usable in two different settings (Collaborative and individualised instructional settings). In FIP development, a lesson plan was used for all the content included in the package. ActionScript 3.0 programming and scripting language and Adobe Flash Professional were used for all the content animations, transitional navigation, backend workings, and the overall interface structure of the FIP. After being recorded, the voice was edited with the Adobe Sound Booth and Adobe Audition before being added to the FIP. The lesson quiz questions were structured with extensible Mark-up Language (XML) and were loaded into the game at runtime to achieve perfect synchrony.

The concept of Physics (light waves) selected for this study is from the senior secondary school class two (SSII) curriculum. The researcher prepared a lesson plan; this covered the scheme of work, produced in video instruction and used for flipping the classroom. The FIP contains a video lesson explaining the concept of Light Waves in Physics. This FIP consists of four lessons for students to access at home and at school. The experimental and control groups were subjected to this instrument (FIP). They were instructed to watch the video after school hours and come the following day to work through problems and engage in collaborative learning discussions on what they had watched. This was done in two different ways: the experimental groups were assigned to three Collaborative Learning (CL) strategies: (i) Pair Share (TPS), (ii) Reciprocal Teaching (RT), (iii) Think-Aloud Pair Problem Solving (TAPPS), while the control group was assigned to Individual Learning (IL) strategy.

The test instrument used in collecting data for this study is a 50-item multiple-choice objective question developed by the researchers from Physics textbooks covering the Concept of Propagation of Waves in Physics. It contains five option answers (A – E), one correct answer, and four distracters. This instrument was used to collect student achievement data after the treatment had been applied. It was used for the pilot testing to find the reliability of the PAT. This PAT was administered to the experimental and the control groups as a pre-test and later administered for the post-test and retention test, respectively. These questions were reshuffled and administered in a random order in the tests. The scoring format is 1 mark per correct answer and zero for a wrong answer.

The validation of the treatments was done in three stages: the content validation was done by three senior lecturers from the Physics Department, Federal University of Technology, Minna, three senior Physics teachers from secondary schools in Minna, three experts from the Test and Measurement Department of National Examination Council (NECO), Minna. Expert validation was done by some groups of experts: computer, Physics, and Educational Technology experts. Field trial validation was conducted on 20 physics senior secondary students from a secondary school in Minna.

Physics Achievement Test (PAT) was subjected to experts' validation about content and face validity by three senior lecturers from the Physics Department, Federal University of Technology, Minna, and three senior physics teachers from secondary schools in Minna, three experts in Test and Measurement Department of National Examination Council (NECO), Minna. PAT was pilot tested on 20 students at Bosso Secondary School, Minna, which is not part of the sampled schools but part of the research population. Thus, they were not used for the real study. The data obtained were subjected to statistical data analysis using split-half reliability, and a reliability value of 0.84 was obtained.

C. Method of data collection

In order to collect the data, the researcher visited the schools to get official permission and cooperation from the school authorities to use the schools and their facilities. The facilities and the students were examined, orientation was conducted for one week, and the pre-test was admi-

nistered. Some physics teachers were trained as research assistants in using FIP, individualised and collaborative learning strategies. The sampling techniques, procedure, and team-building exercise were followed immediately for two weeks.

The four weeks of Physics lessons in the flipped-classroom instructional package, burned on a DVD (digital versatile disc), were distributed to the students through the research assistants. The time frame was given to the students to watch the video lessons/ read the video notes before the class lesson period. During the lesson period, students were assembled into groups. Each group followed specific Collaborative instructional strategies and procedures.

In the first experimental group, think-pair-share (TPS), students engage actively in their learning by collaborating with a partner. The process begins with the instructor posing a question to the class, prompting students to write their responses independently. Following this individual reflection, students share their answers with a peer, fostering a dialogue that allows them to clarify their thoughts and explore points of agreement and disagreement. This method encourages communication and allows the instructor to highlight different perspectives and facilitate a broader classroom discussion. Throughout the process, the teacher, acting as a research assistant, circulates among the groups to ensure adherence to the guidelines established for the TPS method.

The second experimental group employs the reciprocal teaching (RT) strategy, where the focus is on students assuming the role of teachers. In this collaborative environment, students work together to read a shared text or complete a task, taking turns leading the instruction for specific segments. This approach allows students to summarise material, guide discussions, pose questions, and clarify concepts for their peers. The research assistant, serving as a facilitator, actively monitors the interactions in the groups, providing support and encouragement while ensuring that the students effectively engage in their roles as educators.

The third experimental group utilises think-aloud pair problem solving (TAPPS), a method that emphasises problem-solving through verbalisation. In this setup, students work in pairs, where they alternately take on the roles of solver and listener. The solver verbalises their reasoning process as they tackle a problem, while the listener prompts them to elaborate further and seek clarification without providing direct assistance. This technique promotes a deep understanding of problem-solving strategies and encourages active partner engagement. As with the other groups, the research assistant circulates to offer oversight and ensure that the students adhere to the TAPPS guidelines during their interactions.

Finally, the control group employs an individualised learning (IL) strategy, which allows students to learn independently on their terms. This approach allows learners to progress through the material at their own pace, catering to their unique learning needs and abilities. Without the collaborative elements seen in the experimental groups, students in the control group engage in self-directed study, focusing on their individual goals and preferences in the learning process. This specific treatment was given to each group for four weeks. PAT was administered to all the groups after the treatment. The retention test was administered to each of the four groups after two weeks of the post-test. The pre-test, post-test, and retention tests were marked according to the marking scheme, and the results were subjected to data analysis.

RESULT AND DISCUSSION

ln this section, I will present the results of my study, focusing on the differences in achievement and retention scores among students taught Physics using different instructional methods within a flipped classroom context. Specifically, the study compares collaborative learning settings (reciprocal teaching (RT), think-aloud paired problem solving (TAPPS), and think-pair-share (TPS)) with individualised learning (IL).

1. Research question 1

The first research question is: What is the difference in the mean achievement scores of students taught Physics using flipped classrooms in collaborative learning settings—reciprocal teaching (RT), think-aloud paired problem-solving (TAPPS), and think-pair-share (TPS)—compared to those taught using an individualised learning (IL) setting? The mean gain (the difference between pretest and post-test scores) was used to assess improvement across the different learning settings to address this question.

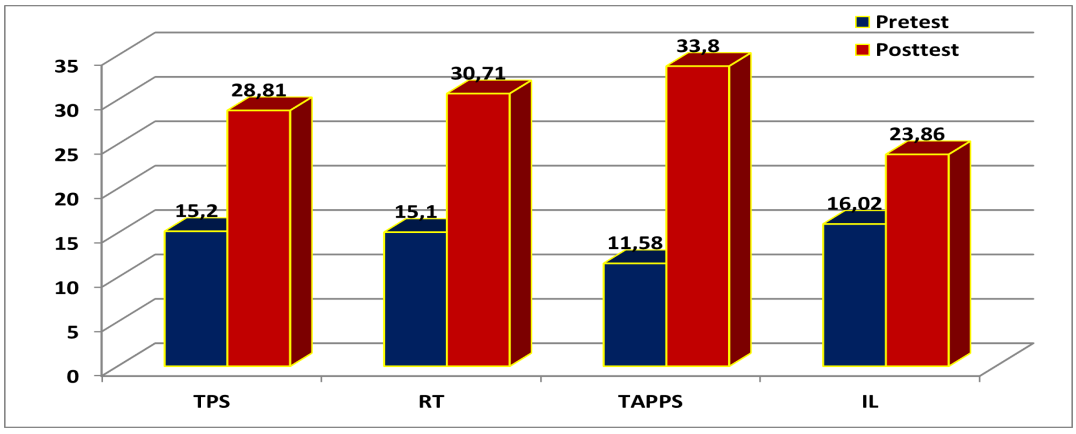
Table 3 Mean gain scores of students taught physics using the flipped classroom collaborative strategies in different learning settings

	Pretest		Post-test		
Learning Setting	**Mean**	**S.D.**	**Mean**	**S.D.**	**Mean gain**
TPS	15.20	4.95	28.81	5.02	13.61
RT	15.10	5.07	30.71	4.01	15.61
TAPPS	11.58	3.69	33.80	2.16	17.65
IL	16.02	2.89	23.86	4.18	7.84

TPS: Think Pair Share, RT: Reciprocal Teaching, TAPPS: Think–aloud Paired Problem Solving, IL: Individualised Learning

Table 3 presents the mean gain and achievement scores of students taught Physics using the three flipped classroom collaborative strategies and the individualised learning (IL) setting. The mean score in the think-pair-share (TPS) group increased from 15.20 in the pretest to 28.81 in the post-test, with standard deviations (S.D.) of 4.95 and 5.02, respectively. The reciprocal teaching (RT) group recorded a mean score of 15.10 in the pretest and 30.71 in the post-test, with S.D. values of 5.07 and 4.01, respectively. The think-aloud paired problem-solving (TAPPS) group led the performance, with a pretest mean score of 11.58 and a post-test mean of 33.80, accompanied by S.D. values of 3.69 and 2.16, respectively. The table also indicates that TPS had a mean gain of 13.61, nearly doubling its pretest score. RT showed significant improvement, with its post-test score doubling the pretest score. Although TAPPS had the lowest pretest score, it demonstrated the highest overall improvement, with post-test scores tripling the pretest scores. Specifically, TAPPS had a pretest score of 11.58 and a post-test score of 33.80, making it the highest-scoring group (Figure 1).

Figure 1 The performance of Physics Students Taught Using TPS, RT, TAPPS, and IL (TPS: Think Pair Share, RT: Reciprocal Teaching, TAPPS: Think–aloud Paired Problem Solving, IL: Individualised Learning).



2. Research question 1

The second research question is: What is the difference in the mean retention scores of students taught Physics using flipped classrooms in collaborative learning settings—reciprocal teaching (RT), think-aloud paired problem-solving (TAPPS), and think-pair-share (TPS)—compared to those taught using an individualised learning (IL) setting? To address this question, the mean retention scores of students taught Physics using flipped classrooms in different learning settings were analysed in Table 5.

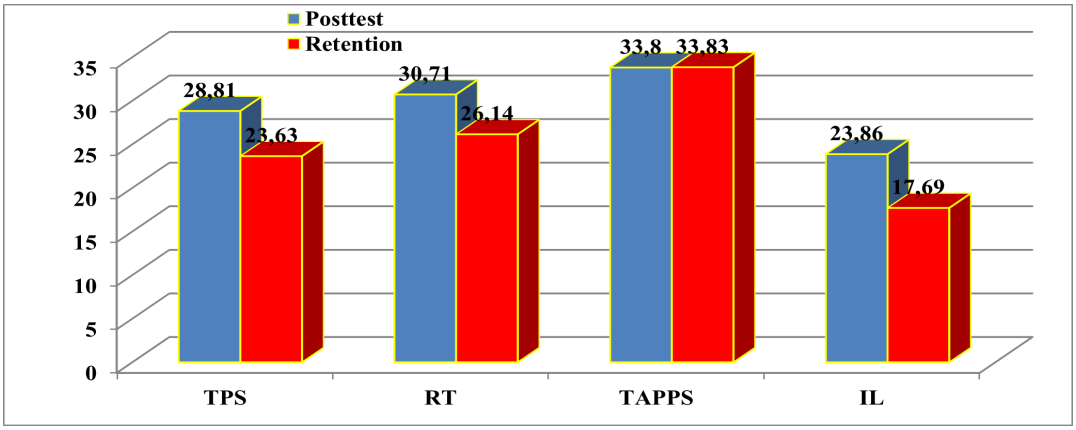
Table 4 Mean retention scores of students taught physics using flipped classroom in different learning settings

Treatment		Pretest		Post-test		
		Mean	S.D.	Mean	S.D.	Mean gain
Experimental	TPS	15.20	4.95	28.81	5.02	13.61
	RT	15.10	5.07	30.71	4.01	15.61
	TAPPS	11.58	3.69	33.80	2.16	17.65
Control Group	IL	16.02	2.89	23.86	4.18	7.84

TPS: Think Pair Share, RT: Reciprocal Teaching, TAPPS: Think–aloud Paired Problem Solving, IL: Individualised Learning

Table 4 shows the mean retention scores of students taught physics using flipped classrooms in different learning settings. From the table, the Think Aloud Pair Group ranked first with a mean retention score of 33.83, followed by the Reciprocal Learning and Think Pair Share with mean scores of 26.14 and 23.63, respectively, all in the experimental group. Individualised learning (control group) was ranked lowest, with a mean retention score of 17.69. The result shows that the experimental group retained more knowledge than the control group. The mean difference, which is the difference in retention and post-test scores, was calculated. TAPPS has the least mean difference, with a mean difference of 0.03, which depicts a minimal increment during the retention test. TPS and RT had mean differences of 5.18 and 4.57, respectively. Conversely, IL (control group) recorded a mean difference of 6.17 (Figure 2).

Figure 2 Mean retention scores of students taught physics using flipped classrooms in different learning settings (TPS: Think Pair Share, RT: Reciprocal Teaching, TAPPS: Think Aloud Paired Problem Solving, IL: Individualised Learning)



3. Research question 3

The third research question is: What is the difference in the mean retention scores of male and female students taught Physics using flipped classrooms in collaborative learning settin-

gs—reciprocal teaching (RT), think-aloud paired problem-solving (TAPPS), and think-pair-share (TPS)—compared to those taught using an individualised learning (IL) setting? To address this question, the mean retention scores across all learning settings (TPS, RT, TAPPS, and IL) were compared based on gender (male and female). T

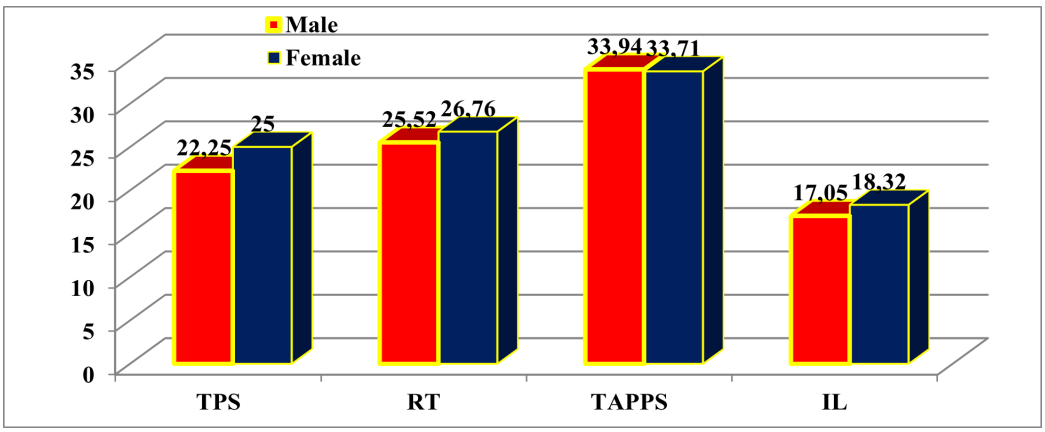
Table 5 Mean Retention scores of students taught physics using flipped classrooms in different learning settings based on gender

Treatment		Retention			
		Male	S.D.	Female	S.D.
Experimental Group	TPS	22.25	1.67	25.00	2.98
	RT	25.52	3.14	26.76	3.74
	TAPPS	33.94	3.38	33.71	3.41
Control Group	IL	17.05	2.90	18.32	4.98

TPS: Think Pair Share, RT: Reciprocal Teaching, TAPPS: Think–aloud Paired Problem Solving, IL: Individualised Learning

Table 5 shows the mean retention scores of the different learning settings in the experimental group compared with those of the control (Individualised learning) group. The result shows that students in collaborative learning settings performed better than the students in individualised learning settings by a wide margin. Although they both benefited from the flipped classroom, the female students benefited most from these learning methods, except in the TAPPS learning setting. From the results of the TPS, the scores were 22.25 and 25.00 for male and female students, respectively. RT learning setting has 25.52 and 26.76 for male and female students, respectively, while TAPPS has 33.94 and 33.71 for male and female students, respectively. IL setting, on the other hand, had 17.05 and 18.32 for male and female students, respectively.

Figure 2 Mean retention scores of male and female students taught Physics using TPS, RT, TAPPS, and IL (*TPS: Think Pair Share, RT: Reciprocal Teaching, TAPPS: Think–aloud Paired Problem Solving, IL: Individualised Learning)



4. Hypothesis testing

Hypothesis One: There is no significant difference in the mean achievement scores of students exposed to the flipped classrooms in collaborative learning settings (Think pair share (TPS), reciprocal teaching (RT), think–aloud paired problem solving (TAPPS) and those taught using individualised learning (IL) settings. In testing hypothesis one, the achievement scores of students exposed to the flipped classrooms in TPS, TAPPS, and RT and those taught with IL flipped classrooms were analysed using ANCOVA, as shown in Table 6.

Table 6 ANCOVA result of students' achievement scores of TPS, TAPPS, RT, and IL learning settings

Source	Type III SUM of Square	df	Mean Square	F	Sig.
Corrected Model	4250.988a	4	1062.747	73.117	.000
Intercept	6923.155	1	6923.155	476.310	.000
Pretest	51.829	1	51.829	3.566	.061
Treatment	4244.418	3	1414.806	97.338	.000
Error	2049.430	141	14.535		
Total	106615.000	146			
Corrected Total	6300.418	145			

Table 6 shows the ANCOVA results of the achievement scores of the group taught using the flipped classroom in Think Pair Share (TPS), Think Aloud Pair Problem Solving and Reciprocal Teaching collaborative settings (experimental group) and Individualised Learning setting (IL) (Control Group). From the table, the F (1,141) = 97.338, $p < 0.05$. This indicates a significant difference among the students' TPS, TAPPS, RT, and IL achievement scores. Hence, hypothesis one is rejected. This reveals that the treatment affects the academic achievement of the four groups. However, Sidak's post-hoc analysis was done to identify the direction of the difference among the treatment groups, as shown in Table 7.

Table 7 Sidak Post-hoc analysis of students' achievement scores of TPS, TAPPS, RT and IL learning settings

Treatment	Treatment	Mean Difference (I-J)	Std. Error	Sig. [a]	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
TPS	RT	-1.722	1.118	.554	-4.706	1.262
	TAPSS	-.536	1.141	.998	-3.581	2.510
	IL	10.939*	1.120	.000	7.950	13.928
RT	TAPSS	1.722	1.118	.554	-1.262	4.706
	RT	1.186	.877	.692	-1.154	3.526
	IL	12.661*	.830	.000	10.446	14.876
TAPSS	TPS	.536	1.141	.998	-2.510	3.581
	RT	-1.186	.877	.692	-3.526	1.154
	IL	11.475*	858	.000	9.186	13.764
IL	TPS	-10.939*	1.120	.000	-13.928	-7.950
	RT	-12.661*	.830	.000	-14.876	-10.446
	TAPSS	-11.475*	.858	.000	-13.764	-9.186

*: Significant at $p < 0.05$

From the post hoc analysis of the post-test mean scores of the groups in Table 7 above, the following conclusions were drawn: A statistical difference was found in the post-test mean score between IL and the other groups. A comparison between TPS and IL revealed a statistically significant difference (mean diff = 10.94, $p < 0.05$) with an upper bound of 13.928. Additionally, comparisons between RT and IL, as well as between TAPPS and IL, showed significant differences (mean diffs = 12.66 and 1.18, respectively, $p < 0.05$), with upper bounds of 14.88 and 13.76, respectively

Hypothesis Two: There is no significant difference in the mean retention scores of students exposed to the flipped classrooms in collaborative learning settings (Think pair share (TPS), reciprocal teaching (RT), think–aloud paired problem solving (TAPPS) and those taught using individualised learning (IL) settings.

Table 8 ANCOVA table of retention mean scores of physics students taught using TPS, RT, TAPPS, and IL

Source	Type III SUM of Square	df	Mean Square	F	Sig.
Corrected Model	5444.484a	4	1361.121	90.034	.000
Intercept	1852.662	1	1852.662	122.548	.000
Pretest	.006	1	.006	.000	.984
Treatment	3225.483	3	1075.161	71.118	.000
Error	2131.625	141	15.118		
Total	104306.000	146			
Corrected Total	7576.110	145			

*: Significant at $p < 0.05$

Table 8 shows the ANCOVA results of the retention scores of the group taught using the flipped classroom in Think-Pair-Share (TPS), reciprocal teaching (RT), Think-Aloud Paired Problem-Solving (TAPPS), and those taught using an individualised learning (IL) setting. From the table, the $F(1,141) = 71.118$, $p < 0.05$. This indicates a significant difference among the students' TPS, TAPPS, RT, and IL achievement scores. Hence, hypothesis two is rejected. This reveals that the treatment affects the students' retention of the four groups. However, Sidak's post-hoc analysis was done to identify the direction of the difference among the treatment groups, as shown in Table 8.

Table 8 Sidak Post-hoc Analysis of Retention Mean Scores of Physics Students Taugh Using TPS, RT, TAPPS, and IL

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig. [a]	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
TPS	RT	5.868*	1.473	.001	1.939	9.798
	TAPPS	-2.651	1.149	.128	-5.718	.416
	IL	-9.819*	1.132	.000	-12.839	-6.799
RT	TPS	-5.868*	1.473	.001	-9.798	-1.939
	TAPPS	-8.519*	1.374	.000	-12.187	-4.851
	IL	-15.688*	1.251	.000	-19.025	-12.350
TAPPS	TPS	9.819*	1.132	.000	6.799	12.839
	RT	15.688*	1.251	.000	12.350	19.025
	IL	7.168*	.843	.000	4.918	9.419
TAPPS	TPS	2.651	1.149	.128	-.416	5.718
	RT	8.519*	1.374	.000	4.851	12.187
		-7.168*	.843	.000	-9.419	-4.918

*: Significant at $p < 0.05$

From the post hoc analysis of post-test mean scores of the groups in Table 8, the following were deduced: In retention mean score, statistical difference was established between all the represented groups except between TAPPS and TPS. Comparison between TAPPS and TPS did not show any significant difference (mean diff = 2.65, p > 0.05) with an upper bound of 0.416.

Hypothesis Three: There is no significant difference in the mean retention scores of male and female students taught Physics using flipped classrooms in collaborative learning settings (reciprocal teaching (RT), think–aloud paired problem-solving (TAPPS) and think pair share (TPS)) and those taught using individualised learning (IL) setting

Table 9 Analysis of Covariance of retention score of Students taught using flipped classrooms in different learning settings concerning gender

Source	Type III SUM of Square	df	Mean Square	F	Sig.
Corrected Model	5856.117a	8	732.015	58.306	.000
Intercept	1788.718	1	1788.718	142.474	.000
Pretest	8.936	1	8.936	.712	.400
Treatment	.230	1	.230	.018	.893
Error	1719.993	137	12.555		
Total	104306.000	146			
Corrected Total	7576.110	145			

Table 9 shows the ANCOVA table for the retention score of the groups concerning gender. The result from the table shows that there is no significant difference in the mean retention score, F (1, 137) = 0.18, p = 0.893 (p > 0.05), between the genders, whilst adjusting for post-test. The result shows that there is no significant difference in the mean retention scores of male and female students taught Physics using flipped classrooms in collaborative learning settings (reciprocal teaching (RT), think–aloud paired problem-solving (TAPPS), and think pair share (TPS)) and those taught using individualised learning (IL) setting (p > 0.05). Therefore, hypothesis three is accepted.

5. Discussion

The study revealed that the flipped classroom collaborative learning settings (TSP, RT, TAPPS, and IL) significantly affected the students' achievement in the post-test scores of students in the different learning settings. There is also a significant difference between the groups: those taught using TPS, RT, and TAPPS and those taught using IL. This finding agrees with Hetika et al. (2018), who recorded that applying the collaborative learning strategy method can improve learning motivation and achievement. The result also aligns with the findings of Sumekto (2018), who stated that a collaborative learning strategy stimulates students' participation and performance in reading; it also increases functional communication, discussion, decision-making, and conflict reduction in group learning. The result of this research disagreed with the findings of James (2015), who reported no difference between the educational performances of the two groups on either computational or conceptual tasks, as indicated by their exam scores.

The study also shows that there was no statistically significant difference in the mean achievement scores of male and female students taught Physics using flipped classrooms in collaborative learning settings (reciprocal teaching (RT), think–aloud paired problem-solving (TAPPS) and think pair share (TPS)) and those taught using individualised learning (IL) setting although there are little visible differences. The result agrees with the findings of Adolphus and Omeodu (2016), which shows that gender does not significantly affect students' understanding when taught with a collaborative teaching approach. The study also showed that gender and teaching approaches do

not jointly affect students' conceptual understanding at the secondary school level.

The study also agreed with the findings of Ogunyebi (2013), which revealed a significant difference between the post-test mean scores of students exposed to collaborative and conventional strategies. The study also revealed no significant difference between the post-test mean scores of male and female students exposed to think-pair (collaborative learning strategy) and conventional strategies. On the contrary, this contradicts the study of Cen et al. (2014), which revealed that learning engagement and performance comparisons indicate that female groups tend to work simultaneously and achieve better results, while male group members engage less and work in sequence. The study also disagrees with the work of Lim (2016), which showed a significant difference in the performances of male and female students, where all-female groups obtained the highest mean score.

Furthermore, this study also shows that there is no significant difference in the mean retention scores of male and female students taught Physics using flipped classrooms in collaborative learning settings (reciprocal teaching (RT), think–aloud paired problem-solving (TAPPS) and think pair share (TPS) and those taught using individualised learning (IL) setting. This is in line with the study of Sulisworo (2012), which stated that gender did not significantly affect student learning motivation. The study also agreed with the study of (Ghorbani et al., 2013), which states that students will get motivated to read more if they realise the importance of reading in improving their writing performance.

The findings of this study have significant implications for learning practices, particularly for teachers implementing flipped classroom models. By highlighting the positive impact of collaborative learning settings such as Think-Pair-Share (TPS), Reciprocal Teaching (RT), and Think-Aloud Paired Problem Solving (TAPPS) on student achievement and engagement, the study suggests that teachers reconsider their instructional strategies. These collaborative approaches enhance academic performance and encourage active participation and communication, essential skills in today's educational landscape. Specifically, for STEM subjects like Physics, where conceptual understanding and problem-solving are crucial, the study suggests that adopting a flipped classroom model incorporating these collaborative strategies may improve student outcomes. Teachers are encouraged to integrate these methods into their flipped classroom designs to foster a more interactive and engaging learning environment.

The potential consequences of these findings point to a shift in how educators plan and execute their lessons. A move towards collaborative learning can promote higher student motivation and engagement, ultimately leading to better academic results. Moreover, suppose teachers recognise that gender does not significantly influence learning outcomes in these settings. In that case, they can focus on creating inclusive environments that cater to diverse student needs without gender-based preconceptions. Regarding the effectiveness of flipped classroom types, the study suggests that collaborative learning strategies (e.g., TPS, RT, TAPPS) yield more significant benefits for student achievement compared to individualised learning (IL). This preference likely arises from the interactive nature of collaborative approaches, which encourage peer-to-peer learning and the sharing of diverse perspectives. In conclusion, the study emphasises the transformative potential of collaborative approaches in flipped classrooms, urging teachers to embrace these strategies to create dynamic and engaging learning experiences for their students.

CONCLUSION

In conclusion, this study demonstrates the effectiveness of incorporating collaborative learning strategies and individualised learning within the flipped classroom model, particularly in enhancing student achievement and retention in Physics for senior secondary school students. The findings highlight that when integrated into flipped classrooms, collaborative learning methods significantly improve student performance. Moreover, flipped classrooms, regardless of the specific learning setup (collaborative or individualised), foster greater student involvement in the

learning process. The study also reveals that gender does not play a significant role in student's academic achievement or attitudes in flipped classrooms, suggesting that the teaching mode has a more profound influence on learning outcomes. The results further indicate that the teaching approach and the learning strategies adopted can significantly affect students' academic performance and retention.

In light of these findings, several recommendations have been made to enhance physics teaching in senior secondary schools in Nigeria. First, it is recommended that flipped classroom collaborative learning strategies be adopted to allow students to learn at their own pace in a manner that suits their individual needs. Additionally, educational policymakers should organise seminars and workshops on blended learning to equip teachers with modern teaching techniques. The Ministry of Education should also advocate for transitioning from traditional, teacher-centred methods to more innovative, blended learning models, such as the flipped classroom, to promote improved learning outcomes. Lastly, due to the gender-neutral nature of flipped classrooms, their widespread adoption is encouraged, particularly in subjects where gender disparities may exist.

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