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Intervention in Students' Performance in Basic Science and Technology Using Blended Learning Strategies

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Abstract

Purpose: This study investigated the efficacy of two blended learning approaches—Face-to-Face Learning (FFL) and the Online Laboratory Strategy (OLS)—in improving the academic performance of Basic Eight students in Basic Science and Technology in Benue State, Nigeria. **Methodology:** Employing a quasi-experimental design, the research sampled 210 students from a target population of 27,457 across six secondary schools. Data were collected using the Basic Science and Technology Performance Test (BSTPT), which demonstrated strong internal consistency with a reliability coefficient of 0.88. **Findings:** Analysis of variance revealed a statistically significant difference in the mean performance scores of students exposed to FFL and OLS compared to those taught using traditional demonstration methods, $F(2, 206) = 131.395$, $p < 0.001$. However, no statistically significant gender differences were observed in performance under either FFL ($F(1, 71) = 1.685$, $p = 0.198$) or OLS ($F(1, 68) = 0.048$, $p = 0.828$), suggesting that the effectiveness of both strategies was independent of gender. These findings underscore the pedagogical value of FFL and OLS in enhancing science learning outcomes. **Significance:** Consequently, the study recommends that educational policymakers and teacher education institutions adopt and institutionalize these blended learning strategies within curriculum frameworks. Moreover, sustained investment in teacher training and resource provision is essential to maximize the instructional benefits of these approaches and promote equitable, high-quality science education.

Keywords: Basic Science and Technology, Blended Learning, Face-to-face Learning, Online Laboratory Strategy, Performance, Gender.

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Introduction

The quality of education delivered to a nation's citizens is a critical determinant of its socio-economic development. Sustained national progress necessitates the implementation of a well-structured and effectively administered science and technology education curriculum. Such a curriculum fosters scientific and technological literacy, equipping individuals with the capacity for innovative thinking and rational decision-making, thereby aligning them with globally accepted standards of conduct (Chilbabi et al., 2018).

To address the limitations inherent in traditional science teaching methodologies, Samba and Egbodo (2019) emphasized the importance of instructional strategies that actively engage all learners and stimulate multiple sensory modalities. Unlike traditional instructional approaches that emphasize content delivery through lectures, this student-centered paradigm prioritizes individual learners' needs, capabilities, and interests, thereby fostering a more personalized, engaging, and meaningful educational experience (Bremner et al., 2022). They advocated for teaching methods that transcend conventional lecture-based delivery, arguing for the integration of technology-enhanced, multimodal strategies—such as blended learning models—as a necessary pedagogical evolution. These models encourage the use of sight, touch, and hearing, thereby enhancing memory retention, fostering deeper conceptual understanding, and facilitating students' ability to make meaningful connections between verbal and visual representations of Basic Science and Technology (BST) content.

Importantly, the incorporation of blended learning strategies should not be misconstrued as a displacement of educators or a mechanization of the learning process. Rather, it involves the thoughtful application of programmed digital tools—delivered through laptops, websites, smartphones, compact discs, and other technological platforms—that serve to complement and enrich teacher-led instruction.

Blended learning environments integrate face-to-face classroom interactions with computer-mediated instruction, thereby combining the strengths of traditional teaching with the advantages of digital learning modalities to create a cohesive and effective educational experience (Graham, 2013; Ali et al., 2023). This instructional approach encompasses diverse educational activities, including in-person sessions, live virtual classes, asynchronous learning tasks, and self-paced modules. By allowing students to engage with content flexibly—at their own pace and convenience—blended learning offers a dynamic and effective alternative to conventional pedagogies. Empirical evidence increasingly supports its potential to enhance student achievement, satisfaction, and retention. This method, therefore, leverages the advantages of a teacher-directed classroom setting alongside the interactivity and learner autonomy characteristic of a student-centered online learning environment (Egara & Mosimege, 2024).

The teacher in a traditional classroom instructional setting employs face-to-face driven model for remediation or supplemental instruction in an online environment. IT allows struggling students to progress at their own pace in the ICT driven classroom. The instructional guide, the actual teaching and learning take place concurrently. Usually, display performances and work are permitted in these strategies. The objective of employing a face-to-face-driven model is to enhance learning by simplifying the process, facilitating understanding, analyzing responses, and providing prompt feedback to learners (Dzakira et al., 2006).

The online laboratory approach is another experimental strategy in the study. Here, delivery is in the physical classroom or ICT laboratory. Learning is entirely online or sometimes using dedicated computer laboratory to complete assigned work. This practice enables students to take learning online under the supervision of the teacher and then eventually carry out assignments or complete their classwork in the computer laboratory, thus allowing them much time to learn on their own and answer questions individually (Dzakira et al., 2006).

The choice of these two strategies is because, they are said to be learner- centered, self-paced and are usually introduced in a traditional classroom setting for remediation or supplementary instructional delivery in the physical classroom or ICT laboratory to give students ample opportunity to play and interact with multimedia resources that will help them to learn meaningfully.

There is a drastic and constant reduction in the level of performance by science students in science subjects in Nigeria often attributed to use of non-student-centered methods (Abaidoo, 2018). This implies that the students' academic performance in science subjects depends on instructional approach. The results of ineffective method of instruction are students' poor performance which suggests that the current educational system may be feeble.

A major problem in Nigerian Education in the 21st century is poor performance. There exists poor performance in science activities (generation, advancement, dissemination and application) among Basic Science and Technology students. This poor performance has been linked to over dependence on conventional lecture strategy by teachers, mostly characterized by teacher centeredness, one-short-lesson, listening, chalk-and-talk, dearth of laboratory equipment and rote learning; one teacher to many students in a classroom that is overcrowded. Conventional lecture method is tilted towards examinations and certification rather than understanding. Gender is seen as a biological anatomy employed for the purpose of distinguishing male from female and its related issues are linked to students' performance. Gender imbalance in science and technology and their roles in the future should be a concern for all. It is envisaged that, a shift from the conventional to Blended learning approach may minimize these challenges and then open ways for electronic domains to foster mobile, engaged, intuitive, self-directed, flexible and accessible instruction in and outside of schools. This calls for innovative apps like Face-to-face learning (FFL) model and Online laboratory approach (OLS). The problem put in question form therefore is, what is the intervention effects of Face-face learning model and online laboratory approach on performance of students in BST, Benue State.

1. How do the mean performance scores compare among students taught BST using face-to-face, online laboratory, and demonstration methods?
2. How does the mean performance of male and female students differ when taught BST concepts through face-to-face instruction?
3. How does the mean performance differ between male and female students taught BST concepts using the online laboratory method?

The study tested the following three null hypotheses at a 0.05 level of significance:

1. There is no significant difference in the mean performance scores of students taught BST concepts using face-to-face, online laboratory, or demonstration methods.
2. There is no significant difference in mean performance scores between male and female students when taught BST concepts through face-to-face instruction.
3. There is no significant difference in mean performance scores between male and female students taught BST concepts using the online laboratory method.

Literature Review

The study was anchored on three learning theories: Lev Vygotsky Theory of Social Development, Garrison Anderson and Archer theory of Community of Inquiry (CoL) and Siemens Connectivism Learning Theory. Theory of Social Development propounded in 1962 is the work of a Russian Psychologist, Lev

Vygotsky. This theory is one of the foundational theories of constructivism which this study was underpinned. This theory upholds that learning is fundamentally a social act emphasising on an inspiration for active learning and human-like tutors in the form of software for teaching and learning. It holds that a transformation resulting from interpersonal process translates into an intrapersonal operation emanates from long series of developments. This theory proposed that learning is socially constructed during interactions between people or appliances, and so an embodied or humanoid agent in the form of education software which can deliver lessons and exhibit nonverbal behaviours would necessarily increase the social nature of learning experience. Vygotsky's theory lays emphasis on social learning environment and social situations in which students play an active role in the classroom. The use of face-face learning(FFL) and online laboratory strategy(OLS) provided numerous approaches including the use of tools such as animated videos, e-fora, computers, websites, live chat, video conferences apps, audios, chatbots among others as social teaching and learning environment. This implies that knowledge could be developed from personal interactions with tools. In this study, the use of ICT tools to facilitate learning is seen as the MKOs. The internalisation of ICT tools is expected to lead to improved performance.

Cognitive scaffolding initiatives which involve the use of multimedia, video, WhatsApp, interactive chatbot and animation and other social learning tools may help the Upper Basic students acquire new skills, abilities, scientific literacy and confidence for problem-solving and scientific investigation. When technological tools are provided for students to support knowledge construction, skill acquisition, active participation, and personalized and collaborative instruction, the teacher only remains as a facilitator or guide on the side instead of being a sage on the stage. This gave the students autonomy over their learning. Furthermore, the theory of social development is related to this study in that, Upper Basic students' vocation and collaboration is considered in the theory.

Another learning theory in which this study was underpinned is the theory of Community of Inquiry (CoI) by Garrison et al. (2000). The CoI theory of e-learning is centered on the concept of distinct "presences" that form the foundation of active learning communities in online and blended course environments. This theory emphasizes creating spaces where students engage actively by sharing ideas, information, and perspectives with each other and experts through virtual tools. Specifically, CoI propose that "presence" is a social phenomenon that emerges through the interactions among students and instructors. This theory is relevant to the study in several ways: it emphasised on social connection and interaction, active learning as well as mobile instruction in order to facilitate teaching and learning. Therefore, the teacher should project his/her teaching characteristics through apps, webinars, zoom, emails, videos and video conferences, e-fora, WhatsApps, Facebook, blogs among others.With these tools, teachers should offer optional virtual office hours for students where they can answer students' questions and address their concerns throughout the lesson. The theory and the study beckon on the teachers to use practice assignments, simulations and other interactive activities on electronic domains to support skill development and divergent thinking. The emerging internet and digital technologies employed in this study probably enabled interactions among students, where and when they choose, engaging collaboratively in a purposeful and cohesive group environment. This enhanced students' academic performance by enabling them to manipulate and use the emerging technological tools and devices. Thus, it bridged the digital divide and prepare students to become relevant to themselves and the society at large and advancement of science and technology in Nigeria.

Siemen (2004) proposed connectivism learning theory. According to the theory, learning is a network phenomenon, influenced by socialization and technology. The theorist further suggests that learning—understood as actionable knowledge—can exist beyond the individual, residing within an organization or a database. This approach emphasizes the importance of connecting various specialized information sources, where the relationships that facilitate further learning are considered more critical than one's current knowledge. The theory is related to this study because, the use of FFL and OLS follow the suit of the connectivism theory. Similar to the theory, the study emphasizes the use of visual experience, use of internet, assessment of skills, sharing of skills and knowledge engaged learning among others. In connectivism, the use of multimedia approach to experiments and problem-solving is encouraged, which is also a task before this study. Here, the students need for intuitive searching is applied by the use of FFL and OLS where science activities are made available for them to see how scientists work. After a series of virtual experiments, the students can verify their results in a real laboratory experiment.

Some studies highlight e-learning's impact on performance of students in science subjects; Samba et al. (2020) and Oluyemi et al. (2015), revealed that e-learning significantly boosts student performance. Specifically, it is noted that e-learning leads to enhanced confidence and science process skills among BST students. The studies further averred improved academic success and personal growth in private secondary and tertiary institutions. This suggests that e-learning promotes not only academic achievement but also fosters a self-directed, motivational aspect that contributes to holistic development. However, while Samba et al. specifically measures improvements in science-related skills, Oluyemi et al. focus more broadly on general academic and personal growth, demonstrating the flexibility of e-learning in different academic contexts.

Relatedly, virtual laboratories and collaborative learning are emphasized by Gamberi et al. (2018) and Achor et al. (2018), both of which examined laboratory strategies in science education. Gamberi et al. investigated the use of virtual labs in chemistry, finding that students in collaborative settings outperformed those in individualized ones, with no significant gender difference in collaborative environments. Achor et al., whose study investigated laboratory strategies in Biology, similarly found that students engaged in laboratory-based methods exhibit higher science process skills acquisition than those using traditional teaching methods. These studies share a core conclusion: collaborative, laboratory-focused approaches enhance student achievement and skills acquisition. However, while Gamberi et al. explored virtual, technology-based labs and their impact on gender equity, Achor et al. focused on physical investigative labs, suggesting that hands-on learning strategies, whether virtual or physical, can significantly boost science learning outcomes.

Blended learning's effectiveness in diverse educational settings as studied by Ndioho et al. (2021), concluded that blended learning strategies lead to better academic performance than traditional lecture-based methods, mirroring the findings of both Samba et al. and Oluyemi et al. on e-learning's positive impact. Like Gamberi et al., Ndioho et al. find no significant gender differences, emphasizing blended learning's role in fostering inclusive educational environments. Their study, however, goes a step further in recommending institutional support for blended learning through enhanced ICT resources—an aspect not directly addressed by the other studies.

In summary, these studies affirm that E-learning, whether through virtual labs, blended strategies, or purely online approaches, consistently enhances performance and engagement across age groups and settings. Collaborative learning emerges as a powerful strategy for both virtual and physical environments, suggesting that interaction and hands-on experience play critical roles in modern education. Gender-related findings also emphasize inclusivity, with collaborative and blended methods appearing particularly effective in bridging gender gaps in performance. These findings further underscore the importance of integrating technology in education, adapting it to specific contexts, and providing the necessary resources to maximize its potential benefits.

Method

This study utilized a non-randomized control group, pretest-posttest quasi-experimental design. To ensure that class activities remained uninterrupted during the treatment, intact classes were employed. The population for the study included 27,457 students enrolled in 250 Basic Eight classes across Benue State. A total of 210 students were purposefully sampled for participation in the study.

The sample size of 210 was considered adequate because the study is quasi-experimental where opportunity is needed to be given to students to perform science experiments on a one-on-one basis with the use of personal computers or smartphones. Furthermore, in an experiment which emphasis is on change resulting from treatment, it may be better handled when the subjects are small in sample size for efficient management and control of extraneous variables. Purposive sampling was engaged to select six coeducational schools that have ICT resources (multi-media). In order not to disrupt class activities organize intact classes were used as control and experimental groups.

Instrument

Basic Science and Technology Performance Test (BSTPT) designed by the researchers was used for data collection. The test consists of 35 multiple choice questions. The BSTPT comprises two parts A and B. Part A is on personal data of students while part B has 35 questions each followed by 4 options lettered A-D with one being a correct option. The topics covered in the BSTPT include; concept of work, energy, power, kinetic theory and phenomena of kinetic theory. The topics were chosen because they were part of the scheme of work and the use of blended strategies that involves multi-media resources like pictures, animation and video simulation is capable of concretizing learning experiences that can simplify the concepts for the students.

Three Science and Mathematics Education lecturers validated the instrument. They read through the items to be sure that have addressed all the research objectives. There comments and suggestions guided the researchers to address grammar and to enhance distraction level of the options. The reliability of 0.88 using Kuder-Richardson formula was obtained for BSTPT. K-R20 was utilized because the items have varied difficulties and were dichotomously scored.

Data Collection and Analysis

BSTPT pre-test was delivered to both groups before the treatments. This was done with the help of basic science teachers engaged as assistants in the sampled schools. No feedback was given to the students on their pretest performance. After the pretest, students in the experimental group were treated via blended strategies comprising multi-media resources like animations, video simulations and pictures having a do-it-yourself guide while those in the control group were exposed to same contents via demonstration strategy. The basic science teachers in the sampled schools were trained by the researchers on the use of blended instructional strategy which is a fusion of demonstration strategy and multi-media resources. This was done using the lesson plans on the following topics; concept of work, energy, power, kinetic theory and phenomena of kinetic theory. Students in both groups were exposed same contents for five weeks and then revision. Students in the demonstration class were taught without the multi-media resources and re-administered in the sixth week after treatment to get post-test scores for analysis. Mean and standard deviations were deployed to answer research questions. The hypotheses were tested via Analysis of Covariance (ANCOVA) from Statistical Package for Social Sciences (SPSS) software. The decision was to reject H_o if $P< 0.05$.

Results and Discussions

This section presents and discusses the findings derived from the analysis of data collected to determine the effectiveness of Face-to-Face Learning (FFL) and Online Laboratory Strategy (OLS) on students' academic performance in Basic Science and Technology (BST) in comparison to the conventional demonstration strategy. It further examines the influence of gender on student performance within each instructional strategy. The analysis includes descriptive statistics (mean scores, standard deviations, and mean gains) and inferential statistics (ANCOVA) to test the formulated hypotheses and determine the statistical significance of observed differences across instructional strategies and gender.

The presentation of results begins with the descriptive analysis of pre-test and post-test scores across the three instructional strategies, followed by an evaluation of gender-based performance within each strategy. Subsequent sections provide inferential statistical analyses to test the null hypotheses, thereby establishing whether the observed variations are statistically significant. The findings are discussed in line with existing literature, highlighting implications for pedagogical practice and educational policy.

Table 1

Mean Performance Scores of Students taught BST via FFL, OLS and Demonstration Strategy

Strategies		Pre BSTPT	Post BSTPT	Mean Gain
Face-to-Face Learning (FFL) Strategy	Mean	25.35	68.00	42.65
	N	74	74	
	Std. Deviation	8.31	8.81	
Online Laboratory Strategy(OLS)	Mean	27.60	70.32	42.72
	N	71	71	
	Std. Deviation	10.90	9.02	
Demonstration Strategy	Mean	27.36	48.72	21.36
	N	65	65	
	Std. Deviation	11.02	7.32	

Table 1 displays the mean performance scores of students taught BST using different instructional strategies. For the Face-to-Face Learning (FFL) strategy, the mean score in the pre-test was 25.35, with a standard deviation of 8.31, while the post-test mean score increased to 68.00, with a standard deviation of 8.81. In the Online Learning Strategy (OLS), the pre-test mean score was 27.60 (standard deviation of 10.90), and the mean score at post est level rose to 70.32, with a standard deviation of 9.02. Conversely, students taught BST using the demonstration strategy had a mean score at pretest level of 27.36 (standard deviation of 11.02) but showed a decrease in the post-test mean score to 48.72, with a standard deviation of 7.32. Additionally, the mean gain for the FFL strategy was 42.65, while the OLS strategy had a mean gain of 42.72. In contrast, the demonstration strategy had a mean gain of only 21.36.

Table 2

Mean Performance Scores of Male and Female Students taught BST Concepts using Face-to-Face Learning

Gender		Pre BSTPT	Post BSTPT	Mean Gain
Male	Mean	24.63	67.31	42.68
	N	44	44	
	Std. Deviation	7.13	8.20	
Female	Mean	26.40	69.07	42.60
	N	30	30	
	Std. Deviation	9.44	7.83	
Mean difference				0.08

Table 2 highlights the mean performance scores of male and female students exposed to Basic Science and Technology (BST) concepts through the Face-to-Face Learning (FFL) strategy. Male students recorded a pre-test mean score of 24.63 (standard deviation of 7.13), which increased to 67.31 (standard deviation of 8.20) in the post-test. In comparison, female students had a pre-test mean score of 26.40 (standard deviation of 9.44) and a post-test mean score of 69.07 (standard deviation of 7.83). The mean gain for male students in the FFL class was 42.68, while female students achieved a mean gain of 42.60. The difference between the mean performance scores of male and female students taught BST concepts using the FFL strategy was only 0.08, indicating a close performance level between the two groups

Table 3

Mean Performance Scores of Male and Female Students taught BST Concepts using Online Laboratory Strategy

Gender		Pre BSTPT	Post BSTPT	Mean Gain
Male	Mean	28.35	70.64	42.29
	N	31	31	
	Std. Deviation	9.86	10.50	
Female	Mean	27.02	70.07	42.05
	N	40	40	
	Std. Deviation	11.74	7.83	
Mean difference				0.24

Table 3 illustrates the difference in mean academic performance scores of male and female students taught BST concepts using the Online Laboratory Strategy (OLS). A total of 31 male students and 40 female students participated in the study. Performance mean score for male students during the pre-test was 28.35 (with a standard deviation of 9.86), which increased to 70.64 in the post-test (standard deviation of 10.50). In comparison, female students had a pre-test mean score of 27.02 (standard deviation of 11.74) and a post-test mean score of 70.07 (standard deviation of 7.83). The mean gain for male students taught BST concepts via OLS was 42.29, while achievement mean gain for females was 42.05. The difference in mean performance scores between male and female students taught BST concepts using OLS was 0.24, indicating a relatively small variance between the two groups.

Hypothesis Testing

Table 4

ANCOVA of Performance Scores of the Students taught BST Concepts using FFL, OLS and those taught via Demonstration Strategy

Dependent Variable: PostBSTPT

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	18976.541[a]	3	6325.514	88.399	.000	.563
Intercept	104853.145	1	104853.145	1465.325	.000	.877
PreBSTPT	75.982	1	75.982	1.062	.304	.005
Strategies	**18804.313**	**2**	**9402.157**	**131.395**	**.000**	**.561**
Error	14740.583	206	71.556			
Total	862426.000	210				
Corrected Total	33717.124	209				

a. R Squared = .563 (Adjusted R Squared = .556)

Table 4 presents the statistical analysis results, showing F(2,206)=131.395, with a p-value of 0.000, which is less than 0.05. Consequently, the null hypothesis is rejected, indicating a significant difference in the mean performance scores of students taught Basic Science and Technology (BST) concepts through Face-to-Face Learning (FFL), Online Laboratory Strategy (OLS), and demonstration strategy. The analysis further suggests that the differences in mean performance scores among these instructional strategies are statistically significant. Additionally, a partial Eta squared value of 0.561 was obtained for the strategies, indicating that 56.1% of the variation in students' performance in BST can be attributed to the instructional strategies employed.

Table 5

Comparisons of Performance Scores of the Students taught BST Concepts via FFL, OLS and those taught with Demonstration Strategy

Dependent Variable: PostBSTPT

(I) Strategies	(J) Strategies	Mean Difference (I-J)	Std. Error	Sig.
Face-to-Face Learning	Online Laboratory Strategy	-2.460	1.411	.229
	Demonstration Strategies	19.155*	1.443	.000
Online Laboratory Strategy	Face-to-Face Learning	2.460	1.411	.229
	Demonstration Strategies	21.615*	1.452	.000

Results in Table 5 presents the bivariate comparisons of various teaching strategies for Basic Science and Technology (BST) and their effects on students' mean performance scores. The comparison between the Face-to-Face Learning (FFL) strategy and the Online Laboratory Strategy (OLS) yielded a p-value of 0.229, which is greater than 0.05, indicating no significant difference in mean performance scores between these two methods. In contrast, the comparison of FFL with the demonstration strategy showed a p-value of 0.000, and similarly, the comparison between OLS and the demonstration strategy also yielded a p-value of 0.000. Both of these results indicate significant differences in mean performance scores. Consequently, the null hypothesis is rejected, confirming that there are significant differences in the mean performance scores of students taught BST concepts using FFL, OLS, and those taught via demonstration strategy.

Table 6

ANCOVA of Performance Scores of Male and Female Students taught BST Concepts via FFL

Dependent Variable: PostBSTPT

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1057.885[a]	2	528.943	8.139	.001	.187
Intercept	42418.512	1	42418.512	652.718	.000	.902
PreBSTPTF	1007.430	1	1007.430	15.502	.000	.179
Gender	**109.505**	**1**	**109.505**	**1.685**	**.198**	**.023**
Error	4614.115	71	64.988			
Total	347848.000	74				
Corrected Total	5672.000	73				

a. R Squared = .187 (Adjusted R Squared = .164)

From Table 6, the analysis reveals F(1,71)=1.685F(1, 71) = 1.685F(1,71)=1.685 with a p-value of 0.198, which is greater than 0.05. Therefore, the null hypothesis is not rejected, indicating that there is no significant difference between the mean performance scores of male and female students taught BST concepts using Face-to-Face Learning (FFL). This suggests that, based on the data analysis, male and female students perform similarly in this instructional setting. Additionally, the partial Eta squared value of 0.023 indicates that only 2.3% of the variation in students' performance scores can be attributed to gender within the face-to-face learning class.

Table 7

ANCOVA of Performance Scores of the Male and Female Students taught BST Concepts with OLS

Dependent Variable: PostBSTPTO

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	46.473[a]	2	23.237	.279	.757	.008
Intercept	43866.150	1	43866.150	526.914	.000	.886
PreBSTPTO	40.796	1	40.796	.490	.486	.007
Gender	**3.958**	**1**	**3.958**	**.048**	**.828**	**.001**
Error	5661.076	68	83.251			
Total	356835.000	71				
Corrected Total	5707.549	70				

a. R Squared = .008 (Adjusted R Squared = -.021)

Table 7 indicates that the analysis yields F(1,68)=0.048F(1, 68) = 0.048F(1,68)=0.048 with a p-value of 0.828, which is greater than 0.05. Therefore, the null hypothesis is not rejected, suggesting that there is no significant difference between the mean performance scores of male and female students taught BST concepts using the Online Laboratory Strategy (OLS). This finding implies that, based on the data analysis, male and female students achieve comparable performance levels in this instructional method. Furthermore, the partial Eta squared value of 0.001 indicates that only 0.1% of the variance in students' performance scores can be attributed to gender within the OLS class.

The findings of the study indicate a significant difference in the mean performance scores of students taught BST concepts through Face-to-Face Learning (FFL), Online Laboratory Strategy (OLS), and those taught using demonstration strategies. The bivariate comparisons affirm the rejected null hypothesis, suggesting that BST concepts are more effectively taught through FFL and OLS compared to demonstration strategies. This conclusion aligns with the research of Gamberi et al. (2018), which found that students in a collaborative learning environment outperformed those in individualized settings when using a chemistry virtual laboratory package. Additionally, this finding supports the work of Abakpa et al. (2016), Achor et al. (2018), and Odoh et al. (2021), which demonstrated that engaging laboratory and e-learning strategies independently enhances acquisition of science process skills and overall performance in biology.

The adoption of both blended learning strategies in this study facilitates a thoughtful integration of FFL and OLS experiences. Students participated in FFL for certain courses while engaging in fully online learning for others. By employing blended learning, the study aimed to provide a rich instructional experience that combines in-person and technology-mediated learning. This approach allows students to connect digitally during online components, which may account for the significant differences observed in mean performance scores among students taught science concepts using FFL, OLS, and demonstration strategies.

Regarding gender and the use of FFL, the study found no significant difference in the mean performance scores of students taught BST concepts. This outcome aligns with the findings of Gamberi et al. (2018), indicating that performance differences between male and female undergraduates in blended learning contexts are not significant. It also corroborates Onyenma and Olele (2020), which showed that gender did not affect the retention of physics content. However, gender stereotyping influenced students' cognitive skills acquisition when FFL was employed, suggesting that FFL is sensitive to gender differences in performance.

In the context of OLS, the findings indicate that there is no significant difference in mean performance scores based on gender among students taught BST concepts. This suggests that OLS is a gender-friendly instructional method. This aligns with Oludipe (2012), who found no significant gender differences in academic achievement at various testing stages, and supports the conclusions, as well as Ode et al. (2019), where gender disparities in students' achievements in e-learning contexts were not significant. Similarly, the study agrees with Ndioho et al. (2021), which found no gender-related performance differences among science education undergraduates. However, this finding contrasts with Gamberi et al. (2018) and Ibenegbu et al. (2020), where significant differences in achievement based on gender were observed.

Overall, the present study found no significant differences in mean performance scores between male and female students exposed to BST concepts via OLS, indicating that OLS is equitable in its effectiveness across genders. The use of blended OLS allows for live videos and other digitally enabled learning opportunities, facilitating primary instructional interactions between students and teachers. This independent approach to learning, where students engage with online lessons, projects, and assignments at their own pace, may explain the lack of significant differences due to in performance scores.

Primary and post primary school children today, often named Generation Z, were born between 2001 and 2020. This generation is characterized by their strong affinity for digital devices, earning them the label of "digital device addicts" or "ICT natives." They value independence and individuality, often seeking autonomy in their learning and work. Additionally, Generation Z prefers to collaborate with millennial managers and innovative coworkers, embracing new technologies as integral to their daily lives and professional aspirations (Achor, 2024), This is in agreement with what Siemen (2004) in his theory of connectivism (learning theory for digital age) said by describing them as 'Net Gen' and which the study was anchored on. Having found that both FFL and OLS are effective and innovative strategies for teaching the crop of Basic eight students science who by their generation are ICT prone, it is an indication of finding the solution to the challenge of poor performance in Basic Science resulting from ineffective teaching strategies.

Secondly the study had to use purposive sampling to select only schools that have required ICT gadgets since most schools are in rural areas. What a contradiction? The contradiction comes from what we have in rural areas in Nigeria (far from exposure to ICT and use of ICT to learn) and it is another worry in this paper. In the face of non-exciting strategies to the learners and means of studies, poor academic performance is imminent. This definitely has obvious implication for school proprietors and government as effort to make relevant ICT gadgets available in all schools should not be optional.

The fact that schools purposively selected were mostly schools in urban and semi-urban locations that have ICT gadgets is an indication that there was bias in sampling through quasi-experimental design which ought not to be affected by no large sample and randomization. It was possible that the network and a limited number of ICT gadgets must have made some schools used not to perform as expected. This implies that the effectiveness of the strategies used in teaching could be higher if all schools used were urban locations but this is subject to replication of the studies in different locations.

Conclusions

This study clearly demonstrates that the use of Face-to-Face Learning (FFL) and Online Laboratory Strategy (OLS) as pedagogical approaches has significantly improved the performance of BST students compared to traditional demonstration strategies. Based on these findings, several recommendations are made:

1. Governments, school proprietors, and non-governmental organizations should allocate funding for the development of adequate instructional materials and applications. This includes procuring tablets, interactive boards, and smartphones, and ensuring high-speed internet connectivity, which are essential for the effective integration and implementation of FFL and OLS.
2. Teacher training institutions should include FFL and OLS applications in their curricula. This will equip both pre-service and in-service BST teachers with the necessary skills and knowledge for the development and practical application of these innovative teaching strategies.
3. BST teachers should actively seek opportunities to attend conferences and workshops focused on FFL and OLS. This continuous professional development will help them stay updated with the competencies and skills required to effectively implement these strategies in their classrooms.
4. Students are encouraged to actively engage with their teachers by demonstrating curiosity, persistence, tolerance, and adaptability to change. Such cooperation will foster a supportive environment that facilitates the effective implementation of FFL and OLS strategies within their schools.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

References

Abaidoo, A. (2018). Factors contributing to academic performance of students in a junior high school. Retrieved November 2020 form: https://www.grin.com/document/450284

Abakpa, V. O., Achor, E. E., & Odoh, C. O. (2016). Effect of laboratory strategy on senior secondary students' achievement in Biology. *Journal of the International Centre for Science, Humanities & Education Research (JISCHER*), 2(2), 68-75.

Achor, E. E. (2024). Overcoming the challenges of using ICT related strategies in teaching science in schools in rural locations in Nigeria. *Monthly Seminar Series of the Science Teachers Association of Nigeria (STAN)* presented 30th September. http://dx.doi.org/10.13140/RG.2.2.26174.91204

Achor, E. E., Odoh, C. O., & Abakpa, V. O. (2018). Use of investigative laboratory strategy in enhancing acquisition of science process skills among senior secondary biology students. *Journal of Research in Curriculum and Teaching*, *1*(1), 103-109.

Ali, A., Khan, R. M. I., & Alouraini, A. (2023). A comparative study on the impact of online and blended learning. *SAGE Open*, *13*(1). https://doi.org/10.1177/21582440231154417

Bremner, N., Sakata, N., & Cameron, L. (2022). The outcomes of learner-centred pedagogy: A systematic review. *International Journal of Educational Development*, *94*, 102649. https://doi.org/10.1016/j.ijedudev.2022.102649

Chilbabi, A., Umonu, S. E, Onah, D. O., & Itodo, E.E. (2018).Effects of Laboratory method on students Achievement and retention in senior secondary biology in Kogi east senatorial zone. *Journal of Research and Method in Education, 8*(6), 31-39.

Dzakiria, H., Mustafa, C. S., & Bakar, H. A. (2006). Moving forward with blended-learning as a pedagogical alternative to traditional classroom learning. *Malaysian Online Journal of Instructional Technology (MOJIT)*, *3*(1), 11-18.

Egara, F. O., & Mosimege, M. (2024). Effect of blended learning approach on secondary school learners' mathematics achievement and retention. *Education and Information Technologies, 29,* 19863–19888. https://doi.org/10.1007/s10639-024-12651-w

Gamberi, A. I., Kawu, H. & Folade, O. C. (2018). Impact of virtual laboratory on the achievement of secondary school chemistry students in homogeneous and heterogeneous collaborative environments. *Contemporary Educational Technology, 9*(3), 246-263. http://dx.doi.org/10.30935/cet.444108

Garrison, D. R., Anderson, T., & Archer, W. (2000). Critical inquiry in a test-based experiment: Computer conferencing in higher education. Internet and Higher Education, 2, 87-105. http://dx.doi.org/10.1016/S1096-7516(00)00016-6

Graham, C. R. (2013). *Blended learning systems: Definition, current trend, and future directions. Handbook of blended learning: Global perspectives, local designs*. Publisher: Pfeiffer Publishing

Ibenegbhu, C., Obiajulu, Q. I., Muojekwu, H.O., Odionye, N., Ngwu,A. N., Ugwu, C. B., & Ugwu, T. U. (2020). Effects of Blended Teaching approach on students Achievement in Biology. *Journal of Engineering and Applied Sciences.15*(12).2623-2629.

Ndioho, O. F., Etokeren, I. S., & Kingdom-Aaron. (2021). Effect of Blended Learning Teaching Strategy on Academic Performance of Science Education Undergraduates in Rivers state University. *Journal of Education and Evaluation, 7*(2),88-93.

Ode, J. O., Ayua, G. A., & Alagwu, T. (2019). *Effect of computer-assisted instruction on upper-basic students' achievement in basic science, Makurdi, Benue State, Nigeria*.

Odoh, C. O., Achor, E. E., & Egbodo, B. A. (2021). Effects of two E-learning strategies on students' performance in Basic

Science and Technology in Benue, Nigeria. *BSU Journal of Science, Mathematics and Computer Education, 2*(2), 40-51.

Oludipe, D. I. (2012).Gender difference in Nigerian junior secondary students' academic achievement in basic science. *Journal of Educational and Social Research*, 2(1), 93-98.

Oluyemi, F., Ayo, C., Ajayi., L., & Okorie, U. (2015). *The impacts of e-learning in facilitating academic performance among private secondary schools and tertiary institutions in Ota, Ogun State, Nigeria.*

Onyenma, C., & Olele, C. N, (2020) Effect of Blended Learning on students Retention of Physics in federal Colleges of Education in south east, Nigeria. *International Journal of Education, Learning Development, 8*(1), 98-116.

Samba, R., & Egbodo, B. A. (2019). Interactive effects of flipped learning model on NCE ii students' critical thinking skills and confidence level in science education in Nigeria. J*ournal of Applied Research in Education (JARE), 6*(2), 71-82.

Samba, R. M. O., Odoh, C. O., & Egbodo, B. A. (2020). Effects of E-Learning on Students' Performance, Confidence Level and Science Process Skills Acquisition in Basic Science and Technology*. IJSRM, 16(1),* 107-126. http://dx.doi.org/10.13140/RG.2.2.21002.29127

Siemens, G. (2004). Connectivism: A learning theory for the digital age. *International Journal of Instructional Technology & Distance Learning*, 2, *10302016.*

Vygotsky, L. (1962). *Thought and language (In: E. Hanf-mann & G. Vakar, Trans.).* MIT Press.