SCIENCE EDUCATION

Effects of Flipped Learning and Virtual Laboratory Strategies on Pre-service Chemistry Teachers' Achievement in Quantitative Analysis in Federal Colleges of Education, Southwest Nigeria

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Abstract

The pre-service teachers' performance in practical Chemistry (especially, quantitative analysis) has been observed over the years to be fluctuating in Nigerian Federal Colleges of Education, which may be attributed to the predominance of teacher-centered mode of instruction. The advent of educational technology provides an opportunity to address these concerns through innovative strategies for teaching Chemistry practical's for proper understanding. This study investigated the effects of flipped learning and virtual laboratory strategies on pre-service Chemistry teachers' achievement in Quantitative Analysis in Federal Colleges of Education in Southwest, Nigeria. The study adopted pretest-posttest, control group, quasi-experimental design. The population for the study comprised of all 100 level pre-service Chemistry teachers from the Federal Colleges of Education, Southwest, Nigeria, one hundred and sixty-eight intact Part 1 pre-service Chemistry teachers were purposively selected from three Federal Colleges of Education in Southwest Nigeria. The Quantitative Analysis Achievement Test, (QAAT) (KR20=0.87) and Instructional guides were used for data collection. The data were analyzed using the mean, standard deviation, Analysis of Covariance. One hypothesis was generated and tested at 0.05 level of significance. There was significant main effects of treatments on pre-service Chemistry teachers' achievement ($F(2, 155) = 1323.788$; partial $\eta^2 = 0.945$). Participants in flipped learning strategy ($\overline{x} = 32.99$) had the highest achievement score followed by those in virtual laboratory instructional strategy ($\overline{x} = 23.00$) and those in the conventional control ($\overline{x} = 12.13$) groups. It was concluded that flipped learning and virtual laboratory instructional strategies enhanced student's achievement in Quantitative Analysis. It was recommended that the two instructional strategies should be adopted for improved achievement in Chemistry practical among pre-service Chemistry teachers.

Keywords: Flipped Learning; virtual laboratory; Quantitative Analysis; academic achievement

1 Introduction

The human natural environment encompasses different kinds of incident and occurrence which is correctly described by Science. Science is the pursuit and application of knowledge and understanding of the natural and social world following a systematic methodology based on evidence (Science Council, 2021). Science is recognised as the foundation of contemporary technological advancement throughout the world. Most science courses revolve around Chemistry, which is frequently connected to other scientific disciplines like Physics, Biology, Geology, and so on (Alexiou et al., 2005). Every aspect of Chemistry is best described and understood in terms of the fundamental building blocks of matter: atoms and molecules, which is why Chemistry is known as the science of atoms and

molecules. Chemistry plays a significant role in our daily lives (NCERT, 2015). People develop strong analytical and problem-solving skills through understanding Chemistry. Chemistry is important because everything human does revolve around Chemistry, in fact human body is a composition of chemicals (Lim (2020). The fact remains that the importance of Chemistry will not be diminished over time, so it will remain a promising career path (Herga, 2016). The branch of Chemistry that deals with the determination of the amount or percentage of one or more constituents of a sample is Quantitative analysis (The Editors of Encyclopedia Britannica, 2024). Quantitative analysis involves analyzing substances to ascertain their composition, such as the elements and compounds present in a given sample through calculations. The methods used for quantitative analysis maybe broadly classified as physical and chemical, depending on which properties are utilized. Physical method involves the measurement of some physical quantities like density, refractive index, et cetera. Chemical methods mainly focus on analysis of chemical reactions which includes Titration and Gravimetric analysis. Titration, also referred to as volumetric (quantitative) analysis, is frequently used to determine how much of an analyte's solute is in its solvent. Analysis of neutralisation reactions between acids and bases is one of its most useful applications which involves the titration of an acid against base, the end-point of this reaction is determined by colour changes according to the pH of the solution by a substance known as indicator (Wikipedia, 2024). For a variety of reasons, quantitative analysis is significant in Chemistry and its integration to the pursuit of pure science make it very essential to various practical application. It is utilized for medical diagnostic functions, such as determining a patient's blood cholesterol level (and also for determining the biochemical markers biopsied tissues), it plays a vital role in formulating medicines and processing food products (Onissiphorou, 2024).

Despite the fact that many science and technology courses at Universities, Polytechnics, and Colleges of Education require Chemistry as a prerequisite, and its importance in the society at large, the rate of students' performance in Chemistry examination has been observed to decline and this may be due to the students, school, and teacher factors at West African Examination Council (WAEC), National Examination Council (NECO) and at Advanced Levels (A-levels). According to the chief examiners report, students had weak practical skills and faced difficulties in molar concentration calculations (Alexiou et al., 2005). The abstract nature of Chemistry subject also impairs the learners' practical understanding of the subject which encourage cramming and repetition of facts verbatim and when such attempt failed, the students become discouraged in their ability to perform a specific task and indifferent about learning Chemistry (Adesoji et al., 2019).

In the real-world situations taking cognizance of the limits and problems, looking for appropriate alternatives is inevitable in which the use of educational technologies, more specifically the use of computer in supporting the laboratory methods can be a logical one (Tüysüz, 2010). There has been growing interest in exploring alternative teaching methodologies to enhance students' learning experiences in Science, Technology, Engineering and Mathematics (STEM) education, especially in Chemistry. The main required change in learning to achieve active students' engagement is by use of different methods or learning approach in a student-centered atmosphere. A major fundamental shift in the educational approach is one that recognizes the pivotal height reached by technology and the flexibility enjoyed in the learning process. The movement of technology to the next level is on the alarming rate without forgetting the old one; using the advantages of both, that is, the positives of the old technology with the advantages of the new (Sun et al., 2023). A single online or offline teaching mode cannot meet the evolving needs of discipline development and training a new generation of laboratory talents. Therefore, the exploration of hybrid modes is a crucial area of focus in the current

reform of laboratory teaching. One approach to this current reform is called the Flipped learning. This involves a course or subject in which students participate in online learning off-site in place of traditional homework and then attend the school for face-to-face, teacher-guided practice or projects. The primary delivery of content and instruction is online. Flipped learning is a specific form of blended learning which involve active learning methodology (Ahmed & Indurkhya, 2020; Rodríguez et al., 2019). It means turning learning structures upside down, teachers prepare a presentation and hand it over to their students, they will watch it or read it depending on the format on their own before the class in which the class time will be used for discussion. Flipped learning facilitates rearrangement of the learning activities (Ozbay & Cinar, 2021). The students in flipped classroom learn at home using virtual resources like videos or texts beforehand better prepared for the face-to-face session, before attending the lecture (Ozbay & Cinar, 2021). The videos recording is more efficient and significantly used; this is supported by the fact that it encourages constant learning by listening to the videos again whenever they want for course activities in online environments (Kara & Kayacan, 2023). A flipped learning is a student center instructional strategy in which the students complete their readings at home and work on live problem-solving during class time facilitating increasing total students' engagement and learning (Kavitha & Anitha, 2023). This type of blended learning enhances students to learn just-in-time and provides them with instant and immediate learning opportunities (Dooley & Makasis, 2020). Flipped learning strategy have been shown to improve student's performance and their motivation towards learning (Díaz et al., 2021).

Chemistry, an important subject required for different scientific and medical professional courses like laboratory professionals, medicine and so on, combines both theory and practice. The flipped classroom, a type of blended learning strategy is one in which the students are solely responsible for learning in which there is shifting of instruction to a learner-centered model from teacher centered model, introducing the students to the new topics online outside of school and the classroom time are used for in-depth exploration of the content leading to significant learning opportunities (Jdaitawi, 2019; Singay, 2020). The students take total responsibility for learning the material at their convenience in which they are engrossed in out of class instruction given to them (Garcia-Ponce & Mora-Pablo, 2020). Studies show that flipped instruction increases students' active learning roles in constructing their own knowledge (Awidi & Paynter, 2019). More time can be spent in flipped classroom on problem finding, problem solving and collaboration as students tackle difficult problems in groups with the help of their teacher and mates (Fung, 2020). Many researchers have carried out studies on factors affecting students' performance in flipped learning. The research studies have revealed an extremely important factor affecting the performance of students in flipped learning is the prior knowledge or the pre-class learning which have showed to be strong and significant (Lee, 2023).

The evaluation of students' outcomes in flipped learning strategy revealed improved academic performances in different courses; this was asserted by a study that students in flipped learning had higher academic achievement (Nja et al., 2022). In another research study on the pre-service teachers studying Chemistry at the College of Education in Ghana, the study investigated the effects of Flipped Inquiry-Based Learning approach (FIBL) on Chemistry students' academic achievement and learning experiences. The result of this study revealed a significant increase in students' academic achievement and critical thinking skills in the pre-and post-test scores in experimental classes. It was also reported that FIBL facilitate conceptual understanding, convenience learning environment, peer collaboration, and learning skills (Aidoo et al., 2022).

The effectiveness of the flipped learning as an instructional strategy have greatly increased student academic achievement in Chemistry as revealed from many empirical research studies (Busebala & John, 2020; Oppong et al., 2022; Rohyami & Huda, 2020). A major second-order meta-analysis found that flipped learning have a positive overall impact on academic achievement compared to traditional lecture-based instruction. The study reported that flipped learning tends to improve academic achievement, particularly when implemented with well-structured active learning activities during class time (Sahoo & Mohalik, 2023).

Educator are constantly looking for ways to make knowledge transfer easy, quicker and more effective. In the era of digital devices, there is an opportunity to enable better learning with technology. Virtual laboratory seems to be the natural next step for the evolution of education (Georgiou et al., 2007). A virtual laboratory is the most fascinating breakthrough of the digital age that may be applied to the field of education. The virtual laboratory is a teaching tool that effectively offers direct, hands-on experiment visualization, an interactive virtual environment, and more opportunities to redo failed experiments to further the learning process independently (Ramadhan & Irwanto, 2017; Tatli & Ayas, 2012). Therefore, the use of virtual laboratory overcomes some of the problems faced in traditional laboratory applications and may contribute positively in reaching the objectives of an educational system. Use of simulation programmes can overcome that mistakes which occur as a result of such laboratory conditions or misuse of the laboratory (The Editors of Encyclopedia Britannica, 2024). The risk that may be avoided in which a hazardous experiment can be prepared in computer simulations for students to view the experiments design, run the experiment in computer, and observe the result is one of the greatest benefits of virtual laboratories over the real laboratories. Challenging experiments can be done virtually having advantages of time saving, reduced cost and increased motivation compared to real laboratory which faced lack of equipment, costly materials and dangerous situations (Wong et al., 2020). Flipped learning strategy was used in collaboration with virtual laboratory, this was conducted in an experiment for the course 18EE340 -Digital Systems with two sets of groups: experimental group with virtual laboratory integrated flipped strategy and controlled group with flipped strategy without virtual laboratory. It was revealed from this study that 14.5% improvement is obtained in the experimental group when compared to the controlled group from the assessment test as a result of rapt attention leading to positive outcomes (Schnieder et al., 2022).

The urgent need for Nigeria to gradually and steadily move away from the traditional time-tested methods and techniques of instruction to those based on Information Communication Technology (ICT) necessitates a fundamental shift in emphasis from the teacher to the learner as the center of education. However, Nigeria has not yet completely embraced the idea and implemented ICT-based teaching strategies. Because of this, research on the effects of flipped learning and virtual laboratories on students' achievement in practical Chemistry in a personalised and collaborative context is few in Southwest Nigeria. Despite the increasing popularity of flipped learning and virtual laboratories, there remains a gap in the understanding of their combined effects on students' achievement in Chemistry Quantitative Analysis. This research addressed how these two strategies, when used affect students' academic achievement in learning Chemistry. This study revealed the effects of flipped learning and virtual laboratory Strategies on pre-service Chemistry teachers' achievement in Quantitative Analysis in some Federal Colleges of Education, South- West Nigeria.

1.1 Statement of the problem

Poor performances in pre-service Chemistry teachers' especially in Quantitative Analysis has been observed over many years, most especially since the COVID 19 era in which academic activities were crippled for a long period of time. The performance of students' in practical Chemistry which facilitates meaningful learning is poor in Nigeria (Hamed & Aljanazrah, 2020). The poor performance is attributed to limitation of the teacher to perform simple laboratory activities due to packed classrooms, lack of laboratories or equipment, or inadequate laboratory settings, the cost of conducting experiments and setting up the necessary equipment; the length of time required for planning and implementation; the difficulty of assessing students' performance during practical activities in crowded classrooms. The traditional strategy to teaching Quantitative Analysis in many educational institutions, in which Federal Colleges of Education is included, often relies on teacher-centered methods which limit active student participation, critical thinking, and the ability to apply concepts in practical scenarios. This has led to the concerns regarding the effectiveness of traditional instructional strategies in fostering deep learning and enhancing students' learning outcomes, particularly in both practical and experimental aspect of Chemistry. The advent of educational technology provides an opportunity to address these concerns through innovative strategies, such as flipped learning and virtual laboratory strategies. Flipped learning promotes an active learning environment by allowing students interacting with instructional content outside the classroom, freeing class time for interactive activities. Similarly, virtual laboratories provide a simulated environment where students can conduct experiments without any constraints associated with physical laboratories, such as limited equipment and safety concerns. Despite the potential advantages of these strategies, little were known about their effectiveness in improving learning outcomes of pre-service Chemistry teachers' in Quantitative Analysis in some Federal Colleges of Education. This study examined the effect of flipped learning and virtual laboratories strategies on pre-service Chemistry teachers' achievement in Quantitative Analysis in some Federal Colleges of Education in South West Nigeria.

1.2 Aim and objective of the study

The aim of this study was to determine the effects of flipped learning and virtual laboratory on pre-service Chemistry teachers' achievement in Quantitative Analysis in Federal Colleges of Education in Southwest, Nigeria.

Specifically, the objective of this study is to:

1. determine the main effects of treatment (flipped learning, virtual laboratory and conventional strategies) on pre-service Chemistry teachers' Achievement in Quantitative Analysis in Chemistry in some Federal Colleges of Education in Southwest, Nigeria.

1.3 Hypothesis

Based on the stated objective, the following null hypothesis was tested at 0.05 level of significance.

H_{01}: There will be no significant main effects of treatment (flipped learning, virtual laboratory and Conventional strategies) on pre-service Chemistry teachers' achievement in Quantitative Analysis,

2 Methodology

2.1 Research design

The research design of the study was the quasi-experimental design using 3x1 factorial matrix. It was focused on treatment which were of three levels (Flipped Learning strategy, Virtual Laboratory strategy and conventional strategy). Flipped learning, virtual laboratory and Conventional strategy were the instructional strategies, in which flipped learning and virtual laboratory was used for the experimental groups, while the conventional strategy was used for the Control group. The dependent variable was students' achievement in pretest and posttest in Quantitative Analysis served as moderator variable.

The design is represented as follows:

- E_1: Q_1 X_1 Q_2
- E_2: Q_3 X_2 Q_4
- C: Q_5 X_3 Q_6

where q_1, Q_3 and Q_5 represent pretest for the experimental groups 1, 2 and control group, respectively; Q_2, Q_4 and Q_6 represent posttests for the experimental groups 1, 2 and control group, respectively.

- X_1 (E_1) represents treatment- Experimental group 1 (Flipped Learning).
- X_2 (E_2) represents treatment – Experimental group 2 (Virtual Laboratory).
- X_3 (C) represents Conventional strategy for Control group.

2.2 Population of the study

The population for the study comprised 100 level Chemistry students from the Federal Colleges of Education, Southwest, Nigeria and these include Federal College of Education, (Special), Oyo, Oyo State, Federal College of Education, Osiele, Abeokuta, Ogun State and Federal College of Education, Iwo, Osun State. The population of Chemistry students in Federal College of Education, (Special), Oyo was 52, the population of Chemistry students in Federal College of Education, Osiele, Abeokuta is 60, and the population at Federal College of Education, Iwo was 168. The total population for the study was 280 students of the selected colleges of Education.

2.3 Sample and sampling techniques

The researcher used the purposive sampling technique to select three classes of Part 1 pre-service Chemistry teachers, 52 from Federal College of Education, (Special), Oyo; 60 from Federal College of Education, Osiele, Abeokuta, Ogun State and 168 from Federal College of Education, Iwo. The study adopted Part 1 pre-service Chemistry teachers because the Quantitative Analysis in Chemistry was taught in 100 level.

2.4 Research instruments

Two research instruments were used for this study. These include Quantitative Analysis Concept Test (QACT) and the Instructional Guides: Flipped Learning Strategy Guide (FLSG), Virtual Laboratory Strategy Guide (VLSG), Conventional Strategy Guide (CSG).

2.4.1 Quantitative Analysis Concept Test (QACT)

The Quantitative Analysis Concept Test (QACT) was used for data collection in which the students were given the Quantitative Analysis Concept Test (QACT) as pre-test before the treatment. It was based on the contents of their syllabus. It consisted of forty 40 objectives questions. The QACT was answered by the students. It had two (2) sections.

- **Section A:** This consisted of demographic data of the students. The requested information was the participants' name of the school, gender, level and subject combination.
- **Section B:** This comprised 40 multiple choice questions which were developed to test the students' achievement in Quantitative Analysis in Chemistry. Each item had four options A to D: one correct answer (key) and three distracters. The instrument was scored manually; one mark was awarded for each correct answer while zero was awarded for wrong answer. The total mark obtained was forty 40 marks. The 40-item validated QACT items were administered to 20 Part 1 pre-service Chemistry teachers in a college outside the sampled colleges. The result was used to ascertain the item difficulty of the test and its reliability index was determined using Kuder-Richardson formula 20 (KR-20). Twenty of the items with extreme (high or low) difficulty indices were removed leaving a total of 20 items on the test with a reliability index of 0.87. Items with difficulty level of 40% - 70% were selected; others with difficulty level above 70% and below 40% were discarded for being too difficult or too easy, respectively.

2.4.2 Flipped Learning Strategy Guide (FLSG)

The Flipped Learning Guide (FLG) was used in teaching the students. The material was prepared by the researcher and the guide was a step by step instruction from simple to complex which include.

1. Define Learning Objectives: This involved clearly outlining the specific goals for the quantitative analysis unit, understanding the principles of titration and its calculations. Analyze data and calculate concentration from titration curves. Interpret results and understand the significance of Quantitative Analysis in real-world applications.
2. Prepare Pre-Class Materials: this involve creating video lectures that cover fundamental concepts and techniques in quantitative analysis, such as stoichiometry, titration techniques, use of analytical balances and volumetric glassware, Data interpretation and statistical analysis. Reading materials and annotations:
3. Assign Pre-Class work by distributing the pre-class materials to students, providing clear instructions on what they are expected to learn before coming to class.
4. Prepare In-Class activities: Designing interactive and collaborative activities that build upon the pre-class materials which include problem-solving sessions on quantitative analysis problems in groups, carry out laboratory experiments, data analysis and case studies:
5. Foster an interactive classroom engagement of peer-to-peer interaction of students.
6. Provide feedback and assessment using formative assessments during class to evaluate student understanding and adjust instruction as needed.
7. Reflect and adjust by gathering students' feedback through surveys or discussions to understand what worked and what did not. Reflect on the outcomes of the Flipped Learning Strategy, considering students' performance.

2.4.3 Virtual Laboratory Strategy Guide (VLSG)

The Virtual Laboratory Strategy Guide (VLSG) was used in teaching the students. The material was prepared by the researcher and the guide was a step by step instruction from simple to complex. Virtual Laboratory Strategy Guide is an instructional software which was developed by the researcher for teaching and learning Quantitative Analysis at Federal Colleges of Education. It was used as a treatment to support learning using computer as a medium. The researcher developed Chemistry Virtual Laboratory with 3 components which include: (a) Chemistry lecture note, (b) video of Chemistry practical, (c) Virtual Chemistry Laboratory. The Chemistry lesson plan format enabled the students to read the experimental procedure and guide the teaching of Quantitative Analysis as the core of the study. Video component was recorded using digital camera and editing suite to enable students watch the video of Chemistry practical and the Virtual Laboratory Strategy Guide enabled the students to perform the experiment. VLSG consisted of three topics which include: (a) Introduction to quantitative analysis (b) Preparation of standard solution, and (c) Determination of unknown concentration. Each of these topics was taught for 60-minutes per week. The production of the Virtual Laboratory Strategy Guide was affected through a team of professionals and specialists that include: (a) computer programmers, educational technology experts; Chemistry lecturers and laboratory assistants.

2.5 Methods of data collection

The researcher collected a letter of introduction from the Head of Department, Science Education, Lead City University, Ibadan and visited the sampled institutions in which the letters were delivered to the Heads of Departments of the selected Federal Colleges of Education. The researcher discussed exhaustively with the Head of Science Department and the research assistants in charge of Chemistry in each Colleges. Two research assistants were used in each school making six research assistants in all the Colleges. The consents and cooperation of the six research assistants and the selected students were sought prior to the administration of the instruments to the students.

2.5.1 Training of the participating teachers (research assistants)

For three weeks, the researcher visited the schools to train those lecturers that were used for the different strategies as applicable to each school for the experimental groups. At the end of the training, the researcher requested the teachers to give demonstration lesson which was assessed by the researcher. This was to ensure strict compliance with the instructional strategies. Teachers in the control group were not trained.

2.5.2 Administration of the pretest on the participants

Two weeks was used to administer the pretest in QACT to all the experimental and control groups in the sampled experimental Colleges. During this stage, the experimental groups were exposed to the treatment (intervention) for six weeks by those teachers who had been trained to assist the researcher, while the control group was taught using the conventional strategy. During this period, the researcher visited the schools to assess the situation. At the end of the treatment period, the posttests in QACT was administered on all the groups (the two experimental groups and the control group) for a week.

2.6 Methods of data analysis

The collected data were analyzed using Analysis of Covariance (ANCOVA) with the pretest scores as covariates to test the hypotheses. The ANCOVA was used to single out the initial group differences;

also, the Estimated Marginal Mean (EMM) of the ANCOVA was used to detect the magnitude and the direction of the differences. Where significant effect was detected, Bonferroni post-hoc test was employed.

3 Results and discussion of findings

The post-test achievement scores of the participants by treatment are presented in Table 1.

Table 1. Post-test achievement scores of the participants by treatment.

Treatment	Factor A	Factor B	Mean	SD	*N*
Flipped Learning	1	1	32.9286	2.05555	14
	1	2	33.0000	1.95402	12
	1	Total	32.9615	1.96938	26
	2	1	32.6500	2.30046	20
	2	2	33.4000	1.83787	10
	2	Total	32.9000	2.15519	30
	Total	1	32.7647	2.17505	34
	Total	2	33.1818	1.86793	22
	Total	Total	32.9286	2.05256	56
Virtual Laboratory	1	1	22.7500	2.51661	16
	1	2	24.2500	1.91485	16
	1	Total	23.5000	2.32795	32
	2	1	22.3000	2.21359	10
	2	2	22.7000	2.00278	10
	2	Total	22.5000	2.06474	20
	Total	1	22.5769	2.36936	26
	Total	2	23.6538	2.05801	26
	Total	Total	23.1154	2.26355	52
Conventional Strategy	1	1	12.6111	2.52374	18
	1	2	11.8000	2.20101	10
	1	Total	12.3214	2.40453	28
	2	1	11.5000	1.61791	18
	2	2	12.5714	1.86936	14
	2	Total	11.9687	1.78677	32
	Total	1	12.0556	2.16392	36
	Total	2	12.2500	2.00543	24
	Total	Total	12.1333	2.08682	60
Total	1	1	21.9167	8.66107	48

Treatment	Factor A	Factor B	Mean	SD	N
	1	2	23.7368	8.38172	38
	1	Total	22.7209	8.53732	86
	2	1	22.5625	9.70612	48
	2	2	21.6765	8.97377	34
	2	Total	22.1951	9.36297	82
	Total	1	22.2396	9.15567	96
	Total	2	22.7639	8.66675	72
	Total	Total	22.4643	8.92678	168

Table1 breaks down mean post-test achievement scores by the three groups (Flipped Learning, Virtual Laboratory and Conventional). The table reports mean, Standard Deviation (SD) and number (N) for each cell. With a total of 56 students in the flipped learning group, the mean and standard deviation scores are 32.93 and 2.06 respectively, with a total of 14 students. The mean and standard deviation scores are 33.00 and 1.95 respectively, with a total of 12 students. The mean and standard deviation score are 32.62 and 2.30 respectively, with a total of 20 students, and the mean and standard deviation scores are 33.40 and 1.84 respectively, with a total of 10 students. The mean and standard deviation scores among the 52 students in the virtual laboratory group are 22.75 and 2.52, respectively. With a total of 16 students, the mean and standard deviation scores are 24.25 and 1.91, respectively. With a total of 10 students, the mean and standard deviation scores are 22.30 and 2.21, respectively, while the mean and standard deviation scores are 22.70 and 2.00, respectively, with ten (10) students. Among the 60 students in the conventional strategy group, the mean and standard deviation scores are 12.61 and 2.52, respectively, with a total of 18 students. The mean and standard deviation among the 10 students is 11.80 and 2.20, respectively. The mean and standard deviation scores with 18 students are 11.50 and 1.62, respectively, while the mean and standard deviation scores with 14 students are 12.57 and 1.87, respectively.

3.1 Test of hypotheses

H_{01}: There will be no significant main effect of treatment on pre-service teachers' Achievement in Quantitative Analysis.

The ANCOVA results are presented in Table 2.

Table 2. Analysis of covariance (ANCOVA) of treatment.

Source	Type III sum of squares	*df*	Mean square	*F*	Sig.	Partial η^2
Corrected Model	12612.744	12	1051.062	234.396	0.000	0.948
Intercept	7647.555	1	7647.555	1705.469	0.000	0.917
Treatment	11872.095	2	5936.047	1323.788*	0.000	0.945
Error	695.041	155	4.484			
Total	98088.000	168				
Corrected Total	13307.786	167				

Source: Fieldwork, 2025. * Significant at $p \leq 0.05$.

From Table 2, the corrected model explains an overwhelmingly large proportion of post-test variance (Type III SS = 12612.744; df = 12; Mean Square = 1051.062; F = 234.396; p = 0.000; partial η^2 = 0.948). Treatment effect is very large and highly significant ($F(2, 155) = 1323.788$; $p < 0.001$; partial $\eta^2 = 0.945$). The partial η^2 suggests that treatment alone explains 94.5% of the explainable variance in the model. Practically, the three instructional strategies differ significantly in their effects on the achievement scores. Students' performance in Quantitative Analysis was significantly impacted by the treatment as demonstrated. Consequently, hypothesis 1 was rejected. The Estimated Marginal Means of the treatment groups were calculated in order to investigate the size of the significant main effect across treatment groups; the outcome is shown in Table 3.

Table 3. Estimated marginal means for achievement by treatment and control group.

Treatment	Mean	Std. error	95% CI lower bound	95% CI upper bound
Flipped Learning Based Instructional Strategy	32.987	.292	32.410	33.565
Virtual Laboratory Based Instructional Strategy	22.999	.302	22.403	23.595
Conventional Method	12.125	.281	11.569	12.681

Source: Fieldwork, 2025

Students in the Flipped Learning Based Instructional Strategy had the highest mean achievement score in Quantitative Analysis (32.99), followed by those in the Virtual Laboratory Based Instructional Strategy (23.00) and the Conventional control group (12.13), according to Table 3 and Figure 1. Flipped Learning Based Instructional Strategy > Virtual Laboratory Based Instructional Strategy > Conventional is the representation of this order. The Bonferroni post-hoc test was used across the groups to identify which group causes this substantial main effect of treatment on students' achievement in Quantitative Analysis; the results are shown in Table 4.

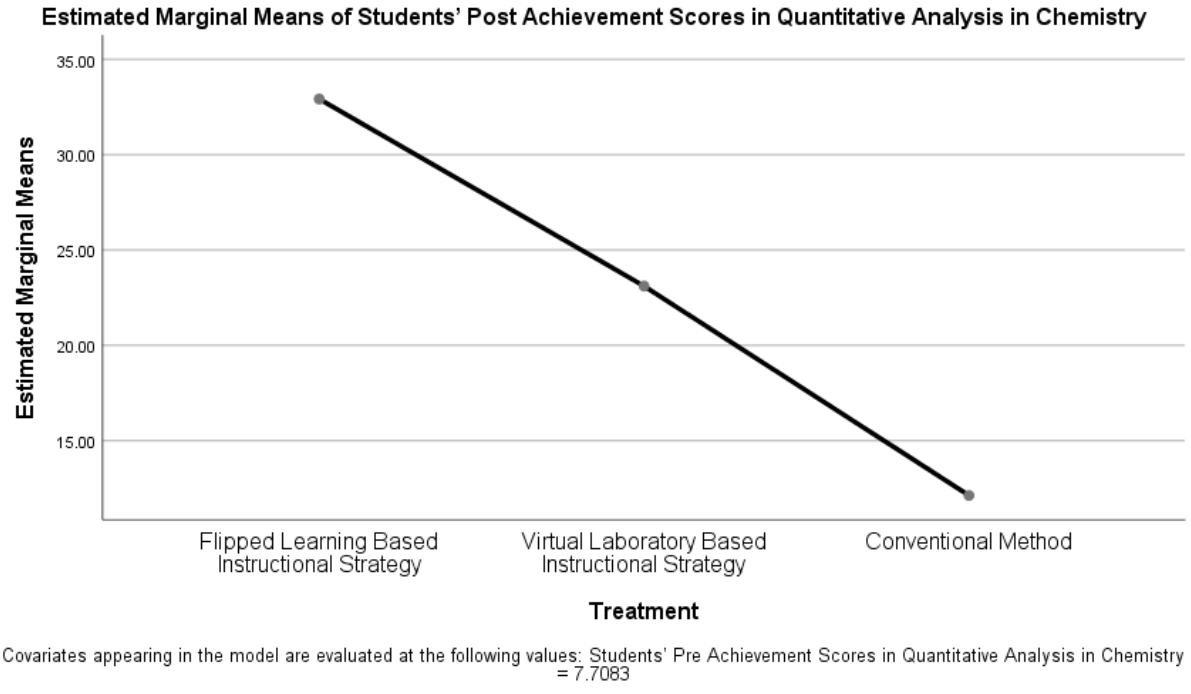


Figure 1. Estimated marginal means for achievement by treatment and control group.

The Bonferroni post-hoc comparisons are presented in Table 4.

Table 4. Bonferroni post-hoc analysis of achievement by treatment and control group.

(I) Treatment	(J) Treatment	Mean difference (I–J)	Std. error	Sig.
Flipped Learning	Virtual Laboratory	9.988*	.420	.000
Flipped Learning	Conventional Method	20.862*	.406	.000
Virtual Laboratory	Flipped Learning	-9.988*	.420	.000
Virtual Laboratory	Conventional Method	10.874*	.413	.000
Conventional Method	Flipped Learning	-20.862*	.406	.000
Conventional Method	Virtual Laboratory	-10.874*	.413	.000

According to Table 4, students in the Conventional Method had considerably lower achievement mean score in Quantitative Analysis than both the Flipped Learning Instructional Strategy and the Virtual Laboratory Instructional Strategy groups. Additionally, students in the Flipped Learning Instructional Strategy have much higher achievement mean score than students in the Virtual Laboratory Instructional Strategy. This suggests that the difference between the treatment groups (Flipped Learning and Virtual Laboratory) and the control group with regard to students' achievement scores in Quantitative Analysis was the cause of the significant difference seen in the ANCOVA result.

3.2 Discussion

The idea that the choice of instructional approach (Flipped, Virtual, Conventional) is the primary determinant of post-test scores in this group is supported by the extremely large effect size and the overwhelmingly substantial treatment effect. There was a significant main effect of treatment on students' achievement in quantitative analysis. In terms of achievement scores in quantitative analysis, students in the Flipped Learning treatment group had the highest mean score (32.93), followed by those in the Virtual Laboratory treatment group (23.12) and the Conventional Method control group (12.13). The outcome demonstrated that the teaching strategies of Flipped Learning and Virtual Laboratory were more successful in raising students' performance in Quantitative Analysis. Students' performance in quantitative analysis improved first with the Flipped Learning instructional style, then with Virtual Laboratory and finally with the traditional approach. The fact that Flipped learning transfer direct instruction outside of the classroom and maintain in-person time for guided problem solving may be the reason why Flipped Learning is an effective teaching technique. This connects activities with greater cognitive demands (application), and quantitative analysis necessitates step-by-step problem solving in a setting that benefits from guided practice. Before laboratory practice, pre-class resources (readings and films) give students frequent access to conceptual explanations, which probably helps students who have trouble with procedural calculations. Students were divided into groups to produce knowledge by transforming their learning experiences and reflecting on their actions through active engagement that emphasizes the individual learning process. This result supports the claim that the method of instruction used affects students' achievement in Chemistry (Helmenstine, 2024; Lumen, 2024; Bredow et al., 2021; Han & Klein, 2019). Also, the result of a research study showed that students who are taught using active learning strategies, like the Flipped Learning and Virtual Laboratory instructional strategies perform better than those who are taught using traditional lecture-based since active learning techniques foster a

deeper understanding of subjects while enabling pupils to think critically and imaginatively (Onissiphorou, 2024; Chen et al., 2023). The results support the claim that Flipped Learning is a cognitive learning approach that aims to bridge the gap between conceptual understanding of the phenomenon and microscopic representation of the phenomenon.

Furthermore, the results support the assertions that the Virtual Laboratory Instructional Strategy is a teaching approach that prioritizes student-centered, experiential learning. The Virtual Laboratory is a teaching tool that successfully provides an interactive virtual environment, direct, hands-on experiment visualization, and more chances to repeat unsuccessful experiments to advance learning on one's own (Li et al., 2022; Farhat et al., 2021). The Virtual Laboratories supports academic endeavors, positively contribute to learning goals by resolving some issues encountered in traditional laboratories (Stratton et al., 2019). The learner-centeredness of the Virtual Laboratory instructional technique may be the reason for the increase in achievement.

4 Conclusion

Based on the study's findings, it can be said that the two strategies: virtual laboratory and flipped learning, were successful in raising students' academic achievement toward Quantitative Analysis at Federal Colleges of Education in Southwest Nigeria. These strategies were effective because they were focused on the needs of the students. Furthermore, the study found that the best method for raising students' academic achievement toward Quantitative analysis was the flipped learning instructional strategy. The techniques preserve in-person time for guided problem solving while shifting direct instruction outside of the classroom. This connects activities with greater cognitive demands (application), and Quantitative Analysis necessitates step-by-step problem solving in a setting that benefits from guided practice. Pre-class movies, in-class problem solving, and fast feedback are examples of interventions that are known to improve learning, according to the instructional guides in the strategies. Additionally, students were able to successfully grasp the concepts and solve problems in Quantitative Analysis due to the two strategies' interactive nature. The study found that the best method for raising pre-service Chemistry teachers' Academic Achievement toward Quantitative analysis was the Flipped Learning Instructional Strategy.

5 Recommendations

Based on the study's findings, the following recommendations were made:

- Flipped learning should be encouraged to manage student expectations (orientation sessions, scaffolding for pre-class work). The efficacy of flipped learning strategy depends on consistent access to pre-class materials (readings, videos), adequate provision of infrastructure and access for Flipped materials should be ensured.
- Virtual laboratories should be used as supplemental resources, particularly in areas where physical laboratories are limited. It is advised that instructors of Quantitative Analysis should abandon traditional teaching methods in favor of using one or both of these cutting-edge strategies.

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