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EFFECTS OF LIVE STUDENT-MADE MODELS STRATEGY ON SENIOR SCHOOL STUDENTS' PERFORMANCE IN ORGANIC CHEMISTRY IN JOS, NIGERIA

BY

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Abstract

This study investigated the effects of the Live Student-Made Models Strategy (LSMS) on the performance of senior secondary II students in organic chemistry. The study adopted a quasi-experimental design with a non-equivalent control group, involving two intact classes. The population of this study was 425 students from senior schools in Jos Metropolis, Nigeria, with a purposive sample of 76 students assigned to either the experimental group (LSMS method) or control group (conventional method). The Organic Chemistry Performance Test (OCPT), developed and validated by experts with a reliability coefficient of 0.89, was used for data collection. Data analysis involved mean, standard deviation, and Analysis of Covariance (ANCOVA). Findings showed that the LSMS group outperformed the control group, when compared to the control. Gender differences were minimal, with female students showing slightly higher improvement. It is recommended that senior secondary school chemistry students adopt the Live Student-Made Models Strategy (LSMS) for learning organic chemistry, as it enhances students' understanding and performance, irrespective of gender.

Keywords: live student-made model strategy, performance, organic chemistry

Introduction

Chemistry at the senior school is one of the core science subjects in Nigeria. The teaching and learning of organic chemistry at the senior school level often present significant challenges for both students and educators. Organic chemistry is known for its abstract concepts, complex molecular structures, and reaction mechanisms, which can make comprehension difficult for students (Kyado et al., 2021).

Conventional teaching methods, such as lectures and textbook-based instruction, may not provide sufficient support for students in visualising and comprehending complex concepts. These traditional approaches often fail to engage students in a way that fosters deep understanding, particularly for abstract or intricate subjects like organic chemistry. As a result, students may struggle to fully grasp key ideas, hindering their ability to apply the knowledge effectively in practical contexts. As a result, there is a growing need for innovative teaching strategies that enhance student engagement and improve academic performance in organic chemistry.

Chemistry is concerned with the study of matter, specifically its structure, properties, and behaviour during chemical reactions (Ababio, 2018, Saibu et al., 2023). Within the Nigerian secondary school curriculum, organic chemistry forms a critical component of senior school chemistry. According to the Nigerian Educational Research and Development Council (NERDC, 2009), one of the primary objectives of senior secondary school chemistry is to prepare learners for further studies in chemistry and related disciplines at the tertiary level. These fields include: Medicine, Pharmacy, Industrial Chemistry, Biology, Chemistry, Physics, Health Education, Agricultural Science, Computer Science, Engineering among others. The significance of chemistry is evident across various fields, as its applications contribute to improving quality of life, economic development, and technological advancement. This aligns with the objectives of Nigeria's National Policy on Education, which emphasises the role of science and technology in national progress (FRN, 2014). However, the subject presents certain challenges, particularly in areas such as organic chemistry, due to its complex three-dimensional molecular structures (Gyamfi & Asaki, 2022). Organic Chemistry is useful in our daily lives. For instance, it is useful in medicine for proper living, to chemists and pharmacists for synthesizing drugs that relieve pain, useful in biochemical principles and biotechnology to explore some chemical reactions, and useful in making plastics, perfumes and fragrances among others (Collini *et al.*, 2023). These products are useful to human beings in different areas to make life easy and comfortable. Learners require an activity-based strategies and hands-on-activity to make the learning of chemistry effective than the conventional method because of its importance in the society.

Between 2018 and 2022, the percentage of students who passed chemistry fluctuated, with scores recorded as 58.17% (2018), 77.02% (2019), 89.89% (2020), 85.44% (2021), and 65.78% (2022). These variations indicate inconsistencies in performance, with some years showing improvement while others experienced declines. Notably, the failure rate in 2018 was as high as 41.83%. Several factors have been linked to students' poor performance in chemistry, including insufficient instructional resources, ineffective teaching strategies, and the extensive nature of the chemistry curriculum (Aquino & Bautista, 2022). Various studies have also highlighted these performance inconsistencies (Adu-Gyamfi *et al.*, 2020; Nja *et al.*, 2020; Chado *et al.*, 2024). Due to the limitations and inconsistencies of traditional methods, one strategy that could enhance students' understanding of complex concepts in organic chemistry is the Live Student-Made Models Strategy (LSMS). This approach involves students actively constructing and utilising three-dimensional models to represent organic molecules and reactions, thereby fostering a deeper and more interactive learning experience. This hands-on approach allows students to engage in experiential learning, where they can physically manipulate models to better understand molecular structures, spatial arrangements, and reaction mechanisms. The LSMS strategy promotes collaborative learning, critical thinking, and deeper conceptual understanding, which are essential for mastering organic chemistry (Ahmed *et al.*, 2024).

Wali and Kanaba (2023) referred to live student-made models as a tool for empowering a class and students to see how an answer can be developed from something. The author argued that a large portion of what learners learn can be used to change the behaviour of others through the use of modelling. Bandura’s (1977) live student-made model strategy referred to learning as a social behaviour that learners observed from others. The author discovered that learning occurs when students watch others’ social behaviours and model what others do which is achieved through live models. Valeeva *et al* (2023) summarise the research results articles about modelling in science from 2011-2023. The results revealed that learning with models had greater effect on cognitive, affective, social and cultural factors.

Eya and Eze (2020) conducted a meta-analytic study to address the inconsistencies observed in existing research regarding the influence of gender on students’ academic performance in chemistry within the Nigerian context. The aim of their study was to synthesise findings from previous empirical investigations to arrive at a more definitive conclusion on the nature of this relationship. Guided by two research questions and a hypothesis, the researchers adopted a meta-analytic design. The population consisted of all prior studies that examined gender-related differences in chemistry achievement. Using purposive sampling, a total of 62 studies conducted across Nigeria between 1990 and 2017 were selected for analysis. Data were analysed using percentages and statistical transformations, and the Winer combined test was employed to test the hypothesis. The findings revealed that gender had only a marginal effect on students’ academic performance in chemistry, with gender accounting for just 3.8% of the variance. This suggests that the impact of gender on chemistry performance is minimal and remains largely inconclusive.

Itikpo *et al.* (2021) examined the effectiveness of the Model-Lead Test Strategy in enhancing the academic performance of Senior Secondary II students in the hydrocarbon aspect of organic chemistry in Benue State, Nigeria. The study utilised a quasi-experimental design, specifically a non-randomised pre-test, post-test control group design. The population included all Senior Secondary II (SSII) students enrolled in chemistry across secondary schools in Makurdi Local Government Area, Benue State. A sample of 145 students was selected, comprising 76 males and 69 females, drawn from two secondary schools. A stratified random sampling technique was utilised to select Makurdi Local Government Area, which was further divided into two strata: Stratum 1 (Makurdi North and South) and Stratum 2 (Makurdi East and West). Additionally, a simple random sampling technique was employed to select two co-educational secondary schools. The Hydrocarbon Achievement Test (HAT) served as the primary instrument for data collection. This instrument was validated by three experts, and its reliability coefficient was determined to be 0.99 using Kuder-Richardson Formula 20 (KR-20). Analysis of Covariance (ANCOVA) results indicated a statistically significant difference between the pretest and posttest mean performance scores of chemistry students in the experimental and control groups. The findings further revealed that the Model-Lead-Test Strategy (experimental treatment) had a significant positive impact on male students' performance in the hydrocarbon aspect of organic chemistry, as well as a similar effect on female students' performance. Based on these outcomes, it is recommended that chemistry educators incorporate the Model-Lead-Test Strategy in the teaching of organic chemistry, regardless of students' gender or school type, to enhance learning effectiveness.

Demircali and Selvi (2022) explored the impact of model-based science teaching on students' academic achievement and science process skills in a science and technology course in Turkey. The study employed a quasi-experimental pretest-posttest design. A total of 48 seventh-grade students participated, with 26 students assigned to the experimental group and 22 students to the control group. The intervention lasted four weeks, during which the experimental group received instruction through model-based science teaching, whereas the control group followed the standard curriculum using traditional teaching methods. Data collection involved two key instruments: the Achievement Test and the Science Process Skills Scale. The study data were analysed using the SPSS 11.5 software package. The findings indicated that students in the experimental group achieved higher scores in both the performance test and the science process skills scale compared to those in the control group. The study concluded that the model-based science teaching approach significantly enhanced students' academic performance and scientific process skills, suggesting its potential for effective implementation in science and technology courses. Joshua et al. (2022) examined the impact of the ball-and-stick model on Senior Secondary II students' interest and academic performance in stereochemistry in Taraba State, Nigeria. The study utilised stereochemistry learning materials (SLM) for instruction and employed a quasi-experimental pretest-posttest design. The research population consisted of 530 Senior Secondary II students across 20 secondary schools in the Bali Education Zone. The study assigned intact classes to either the experimental group, which utilised the Ball-and-Stick Model, or the control group, which followed the Expository Method. Schools were selected using simple random sampling by balloting, and the sample included 35 students in the experimental group and 45 students in the control group. The study's instruments, the Stereochemistry Performance Test (SPT) and Stereochemistry Interest Inventory (SII), were validated by experts in chemistry education. The reliability of these instruments was determined using Kuder-Richardson Formula 21 (KR-21), yielding a coefficient of 0.81, and Cronbach's Alpha, which produced a coefficient of 0.79.

The data collection process involved administering a pretest for 40 minutes using the Stereochemistry Performance Test (SPT) and Stereochemistry Interest Inventory (SII) to record students' initial scores. Following a four-week intervention, a posttest was conducted using the same instruments, and scores were documented. The collected data were analysed using mean and standard deviation to address the research questions, while a t-test was employed to test the research hypotheses at a 0.05 significance level. Findings revealed a significant difference in the academic performance of students taught stereochemistry using the Ball-and-Stick Model compared to those instructed through the expository method. Based on these results, it is recommended that chemistry educators adopt the Ball-and-Stick Model alongside relevant instructional materials to enhance students' understanding. Furthermore, it is suggested that government agencies and school proprietors ensure the provision of Ball-and-Stick Models in schools to support effective teaching and learning.

Ahmed et al. (2024) explored the use of modelling as an instructional strategy to enhance students' motivation, engagement, and academic performance in chemistry. The study employed a descriptive survey design and involved a sample of 120 respondents, comprising both students and teachers, who were randomly selected from two senior secondary schools and two higher education institutions across two Local Government Areas in Edo State, Nigeria. The research was guided by six research questions, twenty-two questionnaire items, and three null hypotheses. Data were collected using structured questionnaires based on a three-point Likert scale measuring levels of agreement. The collected data were analysed using both descriptive and inferential statistical methods. The results indicated that respondents perceived modelling as an effective instructional strategy capable of enhancing students' motivation, engagement, and academic performance in chemistry. Furthermore, the study found that modelling is a valuable teaching approach, closely linked to other complementary instructional strategies and students' academic outcomes. The findings suggest that integrating modelling with additional teaching methods could further improve and advance chemistry education. The study concludes that teachers should be adequately trained and sensitized on the importance of incorporating modelling strategies into chemistry instruction to optimize learning outcomes.

Research Questions

1. What is the difference in the performance of student when taught organic chemistry using live student-made models and when taught with conventional method?
2. What is the difference of gender on the performance of students' when taught organic chemistry using live student-made models?

Research Hypotheses

The following null hypotheses have been formulated and was examined at a 0.05 level of significance:

$H0_1$: There is no significant difference in the performance of student when taught organic chemistry using live student-made models and those taught with conventional method.

$H0_2$: There is no significant difference of gender on the performance of students' when taught organic chemistry using live student-made models

Methodology

This study adopted a quasi-experimental pretest-posttest design with a non-equivalent control group. The research involved two groups, namely the experimental group and the control group. This design was chosen due to administrative constraints within the senior secondary school system, which did not permit the random assignment of students to the experimental and control groups. As a result, two intact classes were selected for the study, including both male and female students. The structure of the study design is illustrated in Figure 1.Group

Group	Pretest	Treatment	Pottest
E	O_1	X	O_2
C	O_1	-X	O_2

Key:
E = Experimental group
C =Control group

O_1 = Pre-test
X = Experimental Treatment (teaching using live student-made model strategy)
X= Control Treatment (teaching using conventional method)
O_2 = Posttest
The study population comprised all Senior Secondary II students enrolled in public secondary schools within Jos Metropolis, Plateau State, Nigeria. Specifically, the research targeted 425 Senior Secondary II (SS2) students taking chemistry in these public schools. A sample of 76 students (33 males and 43 females) was selected from two intact classes of Senior Secondary II students studying chemistry in Jos Metropolis. The study employed a purposive sampling technique to select two state-owned co-educational senior secondary schools within Jos Metropolis for participation. The Organic Chemistry Performance Test (OCPT) consisted of 50 multiple-choice questions designed by the researcher to assess students' performance in hydrocarbons. The test items were derived from the Senior Secondary School Chemistry Curriculum on hydrocarbons and included four answer options (A–D) for each question. The development of the OCPT adhered to Bloom's Taxonomy of Educational Objectives, with a table of specifications ensuring comprehensive coverage of the topic. Additionally, the instrument was structured to gather demographic information about the students.
The validation process for the research instruments was conducted by three subject-matter experts to assess their face and content validity. To determine the internal consistency of the research instrument, a test-retest reliability assessment was conducted using Senior Secondary School students outside the study location. The Organic Chemistry Performance Test (OCPT) was administered to 20 respondents, and their responses were analysed. The reliability coefficient of the OCPT was established using the Kuder-Richardson Formula 21 (KR-21), yielding a value of 0.89.

The study was conducted over a six-week period. In the first week, the researcher recruited and trained two research assistants, who were chemistry teachers from the selected schools. The training sessions were conducted at their respective schools and lasted two days. In the second week, a pretest was administered to both the experimental and control groups to assess their initial performance levels. For four weeks, the experimental group received instruction using lesson plans, wooden sticks, and live student-made models, with 12 students (six males and six females) participating in hands-on activities to represent hydrocarbon structures. Additionally, students were assigned projects to construct hydrocarbon models using plasticine and plastic straws. In the sixth week, a posttest was conducted to evaluate the effects of live the student-made model strategy on students' learning outcomes.

Descriptive statistical methods, including mean and standard deviation, were utilized to address the research questions. To test the research hypotheses, Analysis of Covariance (ANCOVA) was conducted at a 0.05 level of significance using the Statistical Package for Social Sciences (SPSS) version 25.0. ANCOVA was chosen to account for the effects of covariates, ensuring a more precise evaluation of the data.

Data Analysis and Results

Research Question 1: What is the difference in the performance of student when taught organic chemistry using live student-made models and when taught organic chemistry with conventional method?

Table 1 provides a comparative summary of the mean performance scores of students taught organic chemistry using the Live Student-Made Models Strategy (LSMS) and those taught using the conventional instructional method. The data encompass both pretest and posttest scores, with the objective of evaluating the instructional effect of the LSMS approach relative to traditional teaching.

Table 1

Pretest and Posttest Mean Performance Scores of Students in the LSMS and Control Group

Group	N	Pretest Mean Score	SD	Posttest Mean Score	SD	Mean Gain Score	Mean Score Difference
LSMS	26	28.62	7.85	44.15	12.42	15.53	13.21
Control	50	32.48	7.48	34.80	11.05	2.32	

As presented in Table 1, the LSMS group had a pretest mean score of 28.62 with a (SD = ±7.85). Following the intervention, the same group achieved a posttest mean score of 44.15 and a (SD = ±12.42). This corresponds to a mean gain of 15.53. In contrast, students in the control group began with a slightly higher pretest mean score of 32.48 (SD = ±7.48) but showed only marginal improvement after the instructional period, with a posttest mean score of 34.80 (SD = ±11.05), yielding a mean gain of just 2.32. The results reveal that students taught organic chemistry using the Live Student-Made Models Strategy (LSMS) achieved significantly greater learning gains than those taught through conventional methods. The LSMS group improved by a mean of 15.53 points, compared to just 2.32 points in the control group, with a mean score difference of 13.21 favouring LSMS. This indicates that the hands-on, student-centred LSMS approach enhances conceptual understanding and supports its adoption for more effective organic chemistry instruction at the secondary level.

$H0_1$: There is no significant difference in the performance of student when taught organic chemistry using (a) live student-made models and conventional method

Hypothesis 1:
Table 2 displays the results of the Analysis of Covariance (ANCOVA) conducted to test Hypothesis 1, which posits that there is no significant difference in student performance when taught organic chemistry using live student-made models (LSMS) compared to the conventional method. The ANCOVA controlled for students' pretest scores to isolate the effect of the instructional method.

Table 2
Summary of Analysis of Covariance Showing Significant Differences in the Performance of Students in the LSMS and Control Groups

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	1641.00[a]	2	820.50	6.18	.00
Intercept	4933.32	1	4933.32	37.15	.00
PRETEST	144.38	1	144.38	1.09	.30
GROUPS	1634.78	1	1634.78	12.31	.00
Error	9695.00	73	132.81		
Total	121080.00	76			
Corrected Total	11336.00	75			

a. R Squared = .15 (Adjusted R Squared = .12)

The model yielded a statistically significant result, with the corrected model accounting for a significant proportion of the variance in post-test scores ($F_{(2, 73)} = 6.18, p < .001$). The pretest scores themselves did not significantly predict the post-test outcomes ($F_{(1, 73)} = 1.09, p = .30$), suggesting that initial ability levels were adequately controlled. Most notably, the effect of the instructional group was statistically significant ($F_{(1, 73)} = 12.31, p < .001$), indicating a meaningful difference in performance between the LSMS and control groups. There was a statistically significant difference in student performance based on instructional method, with students taught using the Live Student-Made Models Strategy outperforming those taught through the conventional method. The null hypothesis was therefore rejected, affirming the superior effectiveness of the LSMS approach in improving learning outcomes in organic chemistry.

Research Question 2: What is the influence of gender on the performance of students' when taught organic chemistry using live student-made models

To investigate this, Table 3 displays the pretest and posttest mean scores of male and female students in the LSMS group, enabling a comparison of performance across gender lines.

Table 3
Pretest and Posttest Mean Performance Scores of Male and Female Students in the LSMS Group

Group	N	Pretest Mean Score	SD	Posttest Mean Score	SD	Mean Gain Score	Mean Score Difference
Male	9	28.00	9.49	44.88	9.65	16.88	2.06
Female	19	28.94	7.15	43.76	13.93	14.82	

Table 3 presents the performance comparison between male and female students taught organic chemistry using the LSMS approach. The results indicate that the mean pretest score for male students was 28.00 (SD = ±9.49), which was slightly lower than that of female students, who had a mean pretest score of 28.94 (SD = ±7.15). Both groups demonstrated improvement in their posttest scores, with male students achieving a mean posttest score of 44.88 (SD = ±9.65) and female students attaining 43.76 (SD = ±13.93). This resulted in a mean gain score of 16.88 for males and 14.82 for females. Although male students exhibited a slightly higher mean gain, the higher variability in female posttest scores suggests a wider range of individual performance outcomes. These findings suggest that the LSMS instructional strategy was beneficial for both genders, with marginally greater average improvement observed among male students.

Hypothesis 2:

$H0_2$: There is no significant influence of gender on the performance of students' when taught organic chemistry using live student-made models

Table 4 presents the results of the Analysis of Covariance (ANCOVA) conducted to determine whether gender significantly influenced students' performance in organic chemistry within the Live Student-Made Models (LSMS) instructional group. The analysis controlled for prior knowledge as measured by the pre-test scores.

Table 4

Summary of Analysis of Covariance Showing Significant Differences in the Performance of Male and Female Students in the LSMS Group

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	25.75[a]	2	12.88	.077	.93
Intercept	2981.36	1	2981.36	17.91	.00
PRETEST	18.31	1	18.31	.11	.74
GENDER	8.83	1	8.83	.05	.82
Error	3829.64	23	166.51		
Total	54544.00	26			
Corrected Total	3855.39	25			

a. R Squared = .01 (Adjusted R Squared = -.08)

The corrected model accounted for a very small proportion of the variance in post-test scores ($R^2 = .01$; Adjusted $R^2 = –.08$), indicating a poor fit. The effect of the covariate (PRETEST) was not statistically significant, $F_{(1,23)} = 0.11$, $p = .74$, suggesting that pre-existing differences in students' performance did not meaningfully predict post-intervention scores. Most importantly, the main effect of gender was also not significant, $F_{(1,23)} = 0.05$, $p = .82$. This implies that there were no meaningful performance differences between male and female students who were taught using the LSMS approach. The ANCOVA results revealed no statistically significant effect of gender on student performance when taught organic chemistry using live student-made models. Hypothesis 2 was therefore retained, indicating that the LSMS instructional method fosters a gender-neutral learning environment which does not create gender-based disparities in terms of students' academic performance outcomes.

Discussions

This study examined the effectiveness of the Live Student-Made Models Strategy (LSMS) on senior secondary school students' performance in organic chemistry, with gender as a moderating factor. In response to Research Question 1, findings indicated that students who received instruction using LSMS performed better on the Organic Chemistry Performance Test (OCPT) compared to those taught through control methods. This improved performance may be attributed to the hands-on learning experience, self-constructed models, and enhanced understanding of abstract concepts, such as the structural representation and atomic arrangement of organic compounds. The findings of this study align with those of Itikpo *et al.*

(2021), Demircali & Selvi (2022), Joshua *et al.* (2022), and Ahmed *et al.* (2024), all of whom explored the impact of various instructional strategies on students' performance in chemistry.

Itikpo *et al.* (2021) discovered a statistically significant difference between the pretest and posttest mean scores of students in the experimental and control groups, indicating that the Model-Lead-Test Strategy enhanced students' academic performance in organic chemistry. Similarly, Demircali & Selvi (2022) reported that students exposed to model-based science teaching outperformed their peers in both the performance test and science process skills assessment, further supporting the effectiveness of model-based learning approaches. Additionally, Joshua *et al.* (2022) found a significant difference in the performance of students taught stereochemistry using the Ball-and-Stick Model compared to those instructed through the expository method, reinforcing the role of hands-on instructional techniques in enhancing students' understanding. Furthermore, Ahmed *et al.* (2024) established that respondents perceived modelling as an effective instructional strategy that can motivate, sustain interest, and enhance students' performance in chemistry. Their study suggested that integrating modelling into teaching could improve students' engagement and comprehension.

These findings collectively underscore the importance of interactive, model-based learning approaches in improving students' academic achievement in chemistry. The findings of this study indicate that there is no significant difference in the academic performance of male and female students when taught organic chemistry using the Live Student-Made Models Strategy (LSMS). Both groups demonstrated comparable levels of achievement, suggesting that LSMS is an inclusive teaching approach that effectively enhances students' understanding of organic chemistry, regardless of gender. These results are consistent with the findings of Gongden *et al.* (2020), who also reported no significant performance gap between male and female students. However, the findings contradict those of Mohammed *et al.* (2021), who observed that female students outperformed their male counterparts in chemistry-related assessments.

Conclusion

The findings of this study demonstrate that the Live Student-Made Models Strategy (LSMS) had a greater positive effect on students' academic performance in organic chemistry. In conclusion, the study confirms that LSMS is significantly more effective in enhancing students' understanding and performance in organic chemistry compared to traditional teaching methods irrespective of gender.

Recommendations

Based on the research findings, it was recommended that senior schools chemistry students should adopt LSMS in learning of organic chemistry to enhance students' understanding and performance irrespective of gender.

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