

Effect of an Improvised Plant Cell Model on The Academic Achievement of Secondary School Students in Biology in Minna, Niger State

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ABSTRACT

Persistent underperformance in biology among Nigerian secondary school students, particularly in abstract topics such as cell structure, necessitates innovative pedagogical approaches. Conventional lecture-based methods often fail to facilitate conceptual understanding of microscopic biological structures, contributing to poor academic achievement. This study investigated the effect of an improvised plant cell model on the academic achievement of secondary school biology students in Minna Metropolis, Niger State, Nigeria. A quasi-experimental (pretest-posttest control) group design was employed with 256 Senior Secondary II (SSII) biology students randomly assigned to experimental ($n = 119$) and control ($n = 137$) groups. The experimental group received instruction using an improvised plant cell model constructed from locally available materials, while the control group received conventional lecture-based instruction. Data were collected using the Improvised Plant Cell Model Test (IPCMT), a 30-item multiple-choice instrument with established reliability ($r = 0.88$). Analysis of variance (ANOVA) was used to test hypotheses at $\alpha = 0.05$. The experimental group demonstrated greater improvement in mean achievement scores (mean gain = 10.35, $SD = 5.55$) compared to the control group (mean gain = 2.98, $SD = 4.65$). ANOVA confirmed a significant difference in post-test scores between groups, $F(1, 254) = 123.310$, $p < 0.005$, $\eta^2 = 0.327$, indicating a large effect size. While female students in the experimental group showed slightly higher mean gains (mean gain = 11.81) compared to males (mean gain = 10.06), this difference was not significant, $F(1, 117) = 3.233$, $p = 0.075$. The improvised plant cell model significantly enhanced students' academic achievement in biology compared to conventional teaching methods, with benefits across genders. This study provides empirical support for integrating hands-on, model-based instructional strategies in resource-constrained educational settings.

KEYWORDS: Improvised Instructional Materials, Plant Cell Model, Academic Achievement, Biology Education, Gender Differences

I. INTRODUCTION

Biology constitutes a foundational science discipline essential for understanding the natural world and human life driven from two different Greek words: *bios* (life) and *logos* (study). Biology, as a study, encompasses the scientific investigation of living organisms across multiple organisational levels, from molecular cellular biology to ecosystem dynamics (Hills *et al.*, 2020). The Nigerian Educational Research and Development Council (NERDC) has adapted the biology curriculum to ensure continuity and coherence across senior secondary education levels, recognising the subject's critical role in preparing future professionals for careers in Medicine, Agriculture, Pharmacy, Environmental management, and Biotechnologist to mention a few (Etiubon & Umanah, 2023). Among the fundamental concepts of Biology in Nigerian secondary schools, cell structure, particularly the plant cell, represents a foundation topic that supports subsequent learning in cell division, photosynthesis, tissue organisation, and plant physiology. However, this concept is frequently perceived by students as abstract and difficult (Akinbadewa & Sofowora, 2020). The microscopic nature of cellular organelles renders them invisible to direct observation, creating substantial cognitive barriers for learners who rely on two-dimensional textbook representations or verbal descriptions to construct mental models of three-dimensional structures and dynamic processes. The persistent underperformance of Nigerian students in biology has become a source of considerable concern among educators, parents, and policymakers. Analysis of West African Examinations Council (WAEC) Chief Examiners' Reports from 2018-2022 consistently identifies several contributing factors: limited practical exposure, inadequate utilisation of instructional materials, and predominant reliance on teacher-centred, lecture-based pedagogical approaches (Torgby, 2022). Students frequently report that biology instruction remains heavily theoretical, with minimal opportunities for interaction with concrete objects or models that could facilitate visualisation and comprehension of abstract concepts (Lampai & Sukying, 2023). Idoko and Njoku (2019) further identified additional barriers to effective biology instruction, including inadequate laboratory facilities, unfavourable student attitudes toward learning, time constraints, large class sizes, teacher characteristics, and reliance on ineffective teaching materials. Idoko and Njoku (2019) observed that most Nigerian secondary schools continue to employ conventional teaching methods, limiting student activities to passive listening, receptive learning, and rote memorisation. Although the National Policy on Education emphasises teaching methods such as field studies, guided discovery, and laboratory techniques that address learner needs through relevance and functionality (Etiubon & Umanah, 2023), teachers' failure to implement these approaches compromises curriculum effectiveness.

Improvisation in science teaching refers to the development and utilisation of instructional materials constructed from readily available local resources as substitutes for conventional laboratory equipment. Alonge (2018) defined improvisation as the use of alternatives when actual materials are unavailable in same vain Atadoga *et al.* (2022), expanded this definition to encompass locally produced instructional materials derived from accessible natural resources that replace or supplement unavailable conventional materials while Lukeman (2021) emphasized that improvisation involves local provision of instructional resources to impart adequate and relevant knowledge, skills, facts, and values to learners for enhanced understanding during instruction. The pedagogical rationale for improvisation extends beyond mere resource substitution. Abolade (2019) noted that factory-manufactured or imported instructional materials often reflect foreign cultural contexts, highlighting the need for locally produced alternatives that provide learners with firsthand, culturally relevant experiences in learning. Improvised materials reduce teacher verbalization burden, create clearer conceptual representations, enhance lesson engagement,

facilitate student interaction, and promote intellectual engagement during the learning process (Atadoga & Onalapo, 2018). In the context of this study, an improvised plant cell model for this study was constructed using common classroom materials readily available: cardboard, plastic containers, colored paper, transparent jelly, and string, to represent organelles, including the nucleus, chloroplasts, and vacuole of the improvised plant cell model. Such models, when used for teaching and learning, promote concrete, hands-on learning experiences that enhance memory retention and reduce the abstraction associated with microscopic structures in teaching and learning Biology (Ronoh, 2021; Adamu, 2021). In a resource-constrained educational setting such as many schools within Minna Metropolis, improvisation represents not merely a pedagogical preference but an educational requirement for teaching and learning biology. Gender differences in science achievement have attracted considerable research; some of these studies suggested that boys outperform girls in science subjects due to differential exposure to experimentation, cultural expectations, or teacher bias (Li *et al.*, 2024), while others indicate that gender gaps are context-dependent (Stumm *et al.*, 2021). In Nigeria, socio-cultural norms, resource access, and school environments may differentially influence male and female students. This study examined the effect of an Improved Plant Cell Model on The Academic Achievement of Secondary School Students in Biology in Minna, Niger State.

Despite the recognised importance of biology education, student performance at the secondary level has declined steadily, as evidenced by WAEC reports (2019, 2021). Topics such as plant cell structure remain poorly understood due to their abstract nature and limited opportunities for hands-on, inquiry-based learning. Contributing factors include limited availability of standard laboratory models or microscopes, overcrowded classrooms, teachers' overreliance on lecture-based approaches, and inadequate access to visual or multimedia learning materials. These challenges are particularly pronounced in public secondary schools within Minna Metropolis, where resources are scarce, and laboratory facilities are often inadequate (Idoko & Njoku, 2019). Consequently, many students cannot form accurate mental representations of biological concepts, leading to misconceptions and academic failure. While a prior study of Olanrewaju *et al.* (2021) has demonstrated the positive impact of improvised instructional materials on student learning, there exists a lack of research specifically addressing the use of improvised plant cell models for teaching biology in Niger State. Moreover, few studies have integrated teaching and learning with improvised instruction to explore the combined effect on student achievement. This study addresses this gap by investigating the Effect of an Improved Plant Cell Model on The Academic Achievement of Secondary School Students in Biology in Minna, Niger State. The specific objectives were set to guide this study:

- (a). Construct an improvised plant cell model for teaching biology in Minna, Niger State.
- (b). Determine the effect of the improvised plant cell model on biology students' academic achievement compared to conventional teaching strategies.
- (c). Examine the impact of the improvised plant cell model on male and female secondary school students' academic achievement in plant cell instruction.

II. THEORETICAL SUPPORT OF THE STUDY

A. Mayer's Cognitive Theory of Multimedia Learning (2001)

Mayer's theory postulated that students learn more deeply from words and pictures than from words alone in teaching and learning. The human cognitive system comprises separate visual and pictorial, auditory and verbal processing channels, each with limited capacity for teaching and learning. Therefore, Meaningful learning requires active processing to select, organise, and integrate information to be presented for students. In this study, the improvised plant cell model was used to support enabling learners to encode biological concepts both visually and verbally, as stated in the study of Bolkan (2019), which says improvised models reduce cognitive overload by allowing students to see and manipulate representations, thereby enhancing comprehension.

B. Vygotsky's Social Constructivism Theory (1978)

Vygotsky emphasised the social nature of learning and introduced the Zone of Proximal Development (ZPD), the gap between independent performance and performance with assistance from knowledgeable others. Collaborative learning, a key strategy in this study, enables students to co-construct knowledge, engage in peer teaching, and scaffold toward higher performance levels. Conventional lectured support with an improvised model serves as a mediational tool bridging the ZPD. When students collaboratively learn to draw and label improvised plant cells, the students engage in joint problem-solving, verbal reasoning, and mutual clarification (Alkhudiry, 2022; Qureshi et al., 2023).

III. METHODOLOGY

The study population comprised all Senior Secondary II (SSII) students enrolled in government-owned senior secondary schools within Minna Metropolis, Niger State, with a total student population of 12,433 during the 2024/2025 academic session. Simple random sampling was employed to select two co-educational secondary schools from the list of government-owned senior secondary schools in Minna Metropolis. From each selected school, one intact SSII biology class was randomly selected for participation. The two intact classes were randomly assigned to experimental and control conditions. The total sample comprised 256 students. The Improvised Plant Cell Model Test (IPCMT) was developed as the primary data collection instrument. The IPCMT comprised 30 multiple-choice objective items with four options (A, B, C, and D). Items were constructed based on the SSII biology curriculum content and aligned with Senior Secondary School Certificate Examination (SSSCE) standards. Questions were adapted from WAEC and NECO past examinations and relevant textbooks, ensuring alignment with stated lesson behavioural objectives.

The IPCMT was subjected to a content and face validation by three experts, these experts reviewed the IPCMT items for content relevance, clarity, appropriateness for the target population in alignment with the set out instructional objectives of this study, corrections suggested by experts was done carefully and clearly, additionally the questions gotten from WAEC and NECO past examination had an established validation procedure which provided further confidence in item quality for this study. The initial 30-item pool was refined based on expert feedback before pilot testing. A pilot study was conducted in one school in Minna Metropolis that was not included in the main study, Twenty SSII biology students were randomly selected for the pilot test, the IPCMT was administered, and responses were scored dichotomously (1 for correct, 0 for incorrect), Pearson Product-Moment Correlation (PPMC) formula was applied to a test – retest data, yielding

a reliability coefficient of $r = 0.88$, indicating high internal consistency suitable for research purposes.

Research Questions

The following research questions guided this study:

- (a). What is the impact of an improvised plant cell model on biology students' academic achievement compared to conventional teaching strategies?
- (b). What is the impact of an improvised plant cell model on male and female secondary school students' academic achievement in plant cell instruction?

Research Hypotheses

The following null hypotheses were tested at $\alpha = 0.05$:

H₀₁: There is no significant difference in the mean achievement scores of biology students taught plant cell using an improvised plant cell model and those taught using conventional teaching strategies.

H₀₂: There is no significant difference in the mean achievement scores of male and female biology students taught plant cell using an improvised plant cell model

This study employed a quasi-experimental pretest-posttest control group design. This design was selected because random assignment of individual students to experimental and control conditions was not feasible within intact classroom settings. The design is presented in Table 1.

Table 1: Research Design Illustration

Pretest		Treatment		Posttest
O ₁	→	X ₁	→	O ₂
O ₃	→	X ₂	→	O ₄

Where: O₁, O₃ = Pretest observations, O₂, O₄ = Posttest observations, X₁ = Instruction using an improvised plant cell model, X₂ = Conventional lecture-based instruction

The improvised plant cell model was constructed using locally available materials, including cardboard (cell wall and structural base), colored paper and plastic containers (organelles), transparent jelly (cytoplasm), string (endoplasmic reticulum), and bottle caps (vacuoles and vesicles). The model was designed to be three-dimensional, labelled, and durable for repeated classroom use. Lesson plans incorporating the improvised model with conventional lecture method (instruction) were developed for the experimental group. Parallel lesson plans employing conventional lecture and textbook-based instruction were prepared for the control group.

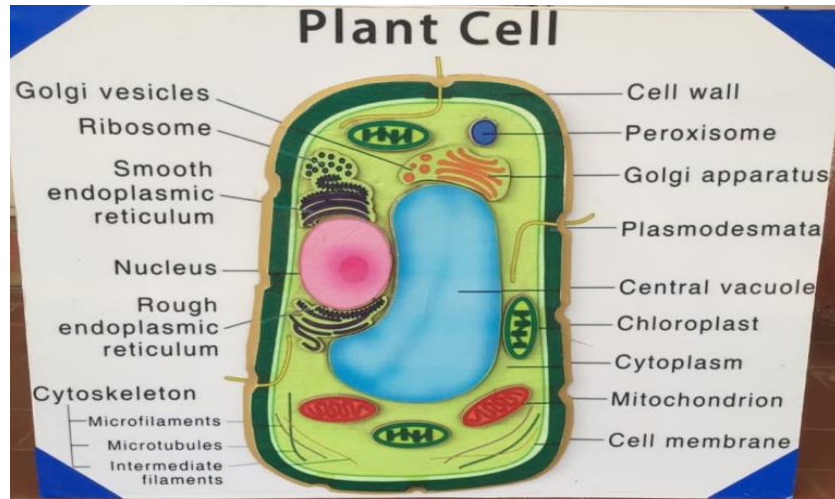


Figure 1: Constructed Structure of Plant Cells (Source: Research Field Work, 2025)

Before data collection, permission letters were obtained from the principals of participating schools. Biology teachers for SSII classes assisted in the random selection of intact classes. The researcher introduced the study to participating classes and explained procedures. The IPCMT was administered as a pretest to both experimental and control groups to assess baseline knowledge and establish group equivalence. The experimental group subsequently received instruction on plant cell structure using the improvised model over two weeks (four 40-minute sessions). The control group received instruction on identical content using conventional lecture methods over the same duration. Following the treatment period, the IPCMT was re-administered as a posttest to both groups, with items reshuffled to minimise testing effects. Data were analysed using descriptive and inferential statistics. Means and standard deviations were computed to answer research questions. Analysis of variance (ANOVA) was employed to test null hypotheses at $\alpha = 0.05$ significance level. Effect sizes were calculated using eta-squared (η^2) to determine practical significance. All analyses were conducted using IBM SPSS Statistics Version 21.0.

IV. RESULTS AND DISCUSSION

Data in Table 2 shows that the experimental group had a mean gain of 10.35 points (SD = 5.55), representing an improvement from the pretest baseline. In contrast, the control group exhibited a mean gain of 2.98 points (SD = 4.65), representing a 38% improvement. The differential gain of 7.37 points between groups suggests that instruction using the improvised plant cell model produced substantially greater learning gains than conventional instruction.

RQ1: What is the impact of an improvised plant cell model on biology students' academic achievement compared to conventional teaching strategies?

Table 2: Descriptive Statistics of Mean and Standard Deviation for Pretest and Posttest Scores by Group

Groups	N	Pre-test		Post-test		Mean Difference
		\bar{x}	SD	\bar{x}	SD	
Experimental	119	7.45	2.94	17.80	5.55	10.35
Control	137	7.74	2.78	10.72	4.65	2.98

Results from Table 3 show that female students had a mean gain of 11.81 points (SD = 5.60), while male students had a mean gain of 10.06 points (SD = 5.45). The difference in mean gains was 1.75 points in favour of female students. Both genders showed substantial improvement from pretest to posttest when taught using the improvised model.

RQ 2: What is the impact of an improvised plant cell model on male and female secondary school students' academic achievement in plant cell instruction?

Table 3: Descriptive Statistics for Male and Female Students within the Experimental Group

Groups	N	Pre-test		Post-test		Mean Difference
		\bar{x}	SD	\bar{x}	SD	
Male	78	7.08	3.25	17.14	5.45	10.06
Female	41	7.24	3.56	19.05	5.60	11.81

Hypothesis Testing

H₀₁: There is no significant difference in the mean achievement scores of biology students taught plant cell using an improvised plant cell model and those taught using conventional teaching strategies.

Table 4: One-way ANOVA Results comparing Posttest Scores between Experimental and Control Groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups (Combined)	3194.927	1	3194.927	123.310	0.000
Within Groups	6581.057	254	25.910		
Total	9775.984	255			

Results from Table 4, the ANOVA revealed a statistically significant difference in posttest mean scores between experimental and control groups, $F(1, 254) = 123.310, p < 0.005$. The effect size ($\eta^2 = 0.327$) indicates that approximately 32.7% of the variance in posttest scores is attributable to the instructional method, representing a large effect according to Cohen's (1988) guidelines. Consequently, H₀₁ was rejected. The improvised plant cell model produced significantly higher academic achievement compared to conventional instruction.

H₀₂: There is no significant difference in the mean achievement scores of male and female biology students taught plant cell using an improvised plant cell model.

Table 5: One-way ANOVA Results comparing Posttest Scores between Male and Female Students within the Experimental Group.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups (Combined)	97.809	1	97.809	3.233	0.075
Within Groups	3539.351	117	30.251		
Total	3637.160	118			

Results from Table 5 show that the ANOVA revealed no statistically significant difference in posttest mean scores between male and female students taught using the improvised plant cell model, $F(1, 117) = 3.233, p = 0.075$. The effect size ($\eta^2 = 0.027$) represents a small effect. Although descriptive statistics indicated higher mean gains for female students, this difference did not reach statistical significance at the alpha level; therefore, H_0 was retained. The improvised plant cell model benefited male and female students equally.

Summary of Findings

- (a). Pretest analysis confirmed group equivalence, with no significant difference between experimental ($M = 7.45, SD = 2.94$) and control ($M = 7.74, SD = 2.78$) groups before treatment.
- (b). The experimental group demonstrated substantially greater improvement (mean gain = 10.35) compared to the control group (mean gain = 2.98).
- (c). ANOVA confirmed a statistically significant difference in posttest scores favouring the experimental group, $F(1, 254) = 123.310, p < 0.005$, with a large effect size ($\eta^2 = 0.327$).
- (d). Within the experimental group, the results of female students showed higher mean gains (11.81) compared to males (10.06), but this difference was not statistically significant, $F(1, 117) = 3.233, p = 0.075$.
- (e). The improvised plant cell model significantly enhanced academic achievement regardless of gender.

Discussion of Findings

The finding shows that students taught using the improvised plant cell model significantly outperformed those taught with conventional instruction within the scope of the study, which aligns with previous research in Nigerian educational contexts. The large effect size ($\eta^2 = 0.327$) observed in this study exceeds those reported in several comparable investigations, suggesting that using an improvised model to teach biological concepts produces benefits for the students beyond the conventional lecture method alone, at least within the area of this study. The significant difference in mean gains (10.35 and 2.98) supported the theoretical evidence that instructional materials facilitate conceptual understanding of abstract biological structures. This finding is in line with the studies of Atadoga and Onalapo (2022), who reported significant achievement differences ($F = 18.62, p < 0.05$) in Kaduna State; Ugwu and Eze (2020), who found significant improvement ($t = 4.37, p < 0.05$) in Enugu State; and Ekundayo (2019), who documented significant differences ($F = 9.74, p < 0.05$) in Lagos State. The replication of positive effects across diverse studies within the Nigerian context strengthens the generalizability of the improvised model's benefits in learning biology within the scope of the study.

The integration of an improvised model with the conventional lecturing method represents a notable contribution of this study. Prior research by Abubakar (2021) in Minna Metropolis and Audu (2022) in Sokoto demonstrated that integrating an improvised model with the conventional lecturing method enhances biology achievement within the scope of the study. The present study extends this work by demonstrating that combining an improvised model with the lecturing method yields substantial learning gains for biology students. This finding supports Vygotsky's (1978) Social Constructivism Theory: peer interaction during model construction creates zones of proximal development wherein students scaffold each other's understanding of organelle structure and function. The non-significant gender difference ($p = 0.075$) found in this study aligns with emerging evidence that well-designed, equitable instructional approaches can mitigate traditional gender disparities in academic achievement of biology students. Although descriptive statistics

conducted in this study favoured the female students (mean gain difference = 1.75). This finding contrasts with some earlier research studies cited, indicating male advantage in science achievement (Li *et al.*, 2024), but at the same time, the findings support more recent findings that gender gaps are context-dependent and can be reduced through appropriate pedagogical interventions (Stumm *et al.*, 2021). The integration of an improvised model with the conventional lecturing method represents a notable contribution of this study, which may create an inclusive learning environment that engages both male and female students to learn biology effectively within the scope of the study.

V. CONCLUSION

This study provides robust empirical evidence that an improvised plant cell model, integrated with a conventional lectured method, significantly enhances secondary school students' academic achievement in biology compared to conventional lecture-based instruction only within the scope of the study. The large effect size indicated that improvised model instruction accounts for approximately one-third of the variance in posttest performance, representing a substantial pedagogical advantage in teaching and learning of biological concepts. Importantly, the study established that the improvised model benefits male and female students in learning biological concepts. Although descriptive statistics revealed a slightly higher gain for the female students, this difference was not statistically significant, supporting the conclusion that well-designed, hands-on instructional approaches can mitigate traditional gender disparities in the academic achievement and retention of biological concepts within the scope of the study.

Based on the study findings, the following recommendations are offered:

- (a). Educators should integrate improvised instructional models into standard teaching practice, particularly for abstract topics.
- (b). Schools should support improvisation culture by providing basic materials and establishing resource centres where teachers can develop and share instructional aids.
- (c). Curriculum planners and regulatory bodies, including NERDC, should explicitly advocate for and incorporate improvised and hands-on learning materials into national biology curriculum guidelines.

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