Equity Journal of Innovative Research in Education
2026, Vol. 3 No. 2
ISSN 2814-2187
OPEN ACCESS
https://ejire.org.ng
An Official Publication of Faculty of Education, AFUSTA

Effect of Model-Based Learning on Biology Drawing Proficiency among Secondary School Students in Birnin Kebbi Education Zone, Kebbi State, Nigeria.

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Citation: Kaoje, A. H., Tambuwal, I. N., & Usman, G. (2026). Effect of Model-Based Learning on Biology Drawing Proficiency among Secondary School Students in Birnin Kebbi Education Zone, Kebbi State, Nigeria. *Equity Journal of Innovative Research in Education,* 3(2), 1-9: ISSN 2814-2187

ABSTRACT

This study investigated the effect of Model-Based Learning (MBL) on the development of Biology drawing proficiency among secondary school students in Birnin Kebbi Educational Zone, Kebbi State, Nigeria. The study was guided by two objectives, two research questions, and two hypotheses. A pretest–posttest quasi-experimental design was adopted. The population of the study comprised all Senior Secondary School Two (SS II) Biology students in public schools within the zone, from which a sample of 208 students was drawn, consisting of 100 males and 108 females. Data were collected using the Biology Drawing Proficiency Test (BDPT), which was validated by experts and yielded a reliability coefficient of 0.82, and data were analyzed using mean and standard deviation, while the independent samples t-test was used to test the hypotheses at 0.05 level of significance. The findings revealed a significant difference in drawing proficiency between students taught using Model-Based Learning and those taught using the conventional teaching method, in favor of the Model-Based Learning group. Furthermore, gender analysis showed that male students performed significantly better than female students in Biology drawing proficiency. The study concluded that Model-Based Learning is an effective instructional strategy for enhancing students' Biology drawing proficiency and recommended that Biology teachers adopt Model-Based Learning over the conventional method to improve students' drawing proficiency and visual understanding of Biology concepts.

ARTICLE HISTORY
Received 28 June 2026
Accepted 25 August 2026

KEYWORDS:
Model-Based Learning (MBL), Drawing proficiency, Biology

1. Introduction

Biology is a fundamental secondary school science subject and a prerequisite for several professional programmes (Kamar, 2018; Laverty et al., 2016). It also emphasizes practical activities that promote observation, experimentation, critical thinking, and scientific inquiry

(Sembiring & Yusuf, 2025). Effective Biology instruction therefore requires approaches that develop conceptual understanding alongside practical skills.

Scientific drawing is an essential Biology practical skill because it enables learners to observe, organize, and communicate biological structures and processes visually (Vojíř et al., 2024; Fiorella & Kuhlmann, 2020). Since external examinations require students to construct and label biological diagrams, drawing proficiency is an important component of Biology achievement. Despite its importance, many secondary school students have difficulty producing accurate biological drawings, applying labels, maintaining proportions, and presenting neat illustrations (Chandra et al., 2020). These weaknesses indicate inadequate development of practical competencies required for effective Biology learning.

One major factor associated with students' poor drawing proficiency is the continued reliance on conventional teacher-centred instructional approaches. Traditional teaching methods typically emphasize lectures, note-taking, and memorization while providing limited opportunities for students to participate actively in practical learning experiences (Amirova, 2025). Such approaches often reduce students' engagement in activities that promote visualization, model construction, and scientific representation, thereby limiting the development of higher-order thinking and practical drawing proficiency. Model-Based Learning (MBL) offers an alternative because it engages learners in constructing, evaluating, revising, and applying models to explain scientific phenomena (Louca & Zacharia, 2012). The approach promotes visualization, reasoning, and active construction of understanding rather than passive reception of information.

In the context of this study, Model-Based Learning was operationalized as an instructional approach in which students learned Biology concepts through direct interaction with physical and visual biological models before producing scientific drawings. During classroom instruction, the teacher presented three-dimensional models, preserved specimens, and charts representations of biological structures (Lombard et al., 2023). Students observed the distinguishing features of each model, discussed their observations in small groups, identified key structural characteristics, and subsequently produced labelled biological drawings based on their observations. The teacher guided learners by providing feedback on accuracy, proportion, labeling, and neatness while encouraging revision and improvement of their drawings. Through repeated observation, discussion, drawing practice, and reflection, students actively constructed biological knowledge and developed drawing proficiency rather than merely copying diagrams from the chalkboard or textbook.

Recent WAEC Chief Examiners' Reports continue to identify weaknesses in candidates' Biology drawings (WAEC, 2024). Although MBL has been associated with improved conceptual understanding and scientific reasoning, evidence on its effectiveness for Biology drawing proficiency among secondary school students in Birnin Kebbi Education Zone remains limited. Evidence on possible gender differences is also insufficient. This gap motivated the present study.

2. Literature Review

Model-Based Learning (MBL) is a learner-centred approach in which students develop, use, evaluate, and revise models to explain scientific structures and processes (Bennett et al., 2020). By representing otherwise abstract biological phenomena, models can support visualization, conceptual reasoning, and meaningful understanding (Wilson et al., 2020).

Biological drawing requires careful observation, appropriate proportion, accurate representation, labelling, and neatness (Ebere & Abugu, 2025). It is also a learning process through which students observe, interpret, and communicate scientific information (Ilah & Bello, 2026). Focused observation and drawing can further support three-dimensional spatial understanding (Shapiro et al., 2020).

The relationship between modelling and academic performance is also supported by evidence from Biology education. Chinyere and Bebia (2020) examined the effect of practical drawing on Biology students’ achievement in the Calabar Education Zone of Cross River State, Nigeria, using a quasi-experimental pretest-posttest control group design involving 160 students. Their findings showed that students exposed to practical drawing performed significantly better than those who did not receive the treatment, while gender had no significant effect on achievement. Although the intervention was practical drawing rather than MBL, the study provides relevant evidence that instructional activities involving active observation and visual representation can contribute to improved Biology achievement. It therefore provides a useful link between the practical skill of drawing and students’ broader academic performance.

Evidence from the Nigerian context also indicates persistent challenges in students’ biological drawing proficiency. Ebere and Abugu (2025) investigated lapses in biological drawings among 2,655 SSII Biology students in the Obollo-Afor Education Zone of Enugu State, using a sample of 266 students selected through multistage sampling. Data collected with the Students’ Biological Drawing Lapses Test were analysed using frequencies and percentages. The findings revealed considerable deficiencies in students’ biological drawings, particularly in appropriate titling, determination of magnification, and observance of drawing-line rules. These deficiencies are important because weaknesses in biological representation can limit students’ ability to communicate scientific observations effectively and may negatively affect their performance in Biology practical examinations. The study consequently highlights the need for instructional approaches that do more than expose students to finished diagrams and instead actively develop their ability to observe and construct biological representations.

Overall, previous studies have emphasized conceptual understanding, scientific reasoning, engagement, or achievement, with less attention to drawing proficiency as a specific outcome of MBL. Nigerian studies have documented weaknesses in biological drawing or examined practical drawing, but evidence on structured MBL in Birnin Kebbi Education Zone is limited. The present study therefore examined MBL and Biology drawing proficiency in this context.

3. Methodology

A pre-test–post-test quasi-experimental design was used with 208 SS II Biology students (100 males, 108 females) selected through multistage sampling from four public secondary schools. Two schools formed the MBL group (Experimental group) and while the other two conventional group (Control group). The instrument used for data collection was Biology Drawing Proficiency Test (BDPT), adopted from WAEC past questions and was validated by two senior lecturers and had a Cronbach's alpha reliability coefficient of 0.82. The intervention lasted for six weeks. Mean and standard deviation answered the research questions, while independent-samples t-tests tested the hypotheses at the 0.05 level of significance.

4. Experimental Procedure

The intervention lasted for six consecutive weeks. Both groups were taught the same Biology topics using identical lesson objectives, instructional time, and curriculum content. The only difference was the instructional strategy employed. In the experimental group, students actively interacted with three-dimensional models, preserved specimens, charts, diagrams, and teacher demonstrations. They were encouraged to observe carefully, identify distinguishing features, discuss their observations in groups, and produce biological drawings based on the models provided. The teacher served primarily as a facilitator, guiding students through observation, discussion, drawing practice, and feedback sessions.

At the end of the six-week instructional period, the Biology Drawing Proficiency Test (BDPT) was re-administered to both groups as a posttest. Students' drawings were scored using a standardized Biology Drawing Proficiency Rating Scale that assessed accuracy, proportionality, labeling, neatness, and overall presentation. The resulting scores were analysed to determine the effect of Model-Based Learning on students' Biology drawing proficiency.

The six-week intervention covered cell structure, plant and animal tissues, the transport system, and the excretory system. In each experimental lesson, students observed three-dimensional models, preserved specimens, charts, or multimedia representations; discussed structural features in groups; produced labelled drawings; and received teacher or peer feedback. The control group covered the same topics and duration through conventional teacher explanation and textbook/chalkboard diagrams. Week 1 involved orientation/introduction and pre-testing, Weeks 2–5 covered the four topics, and Week 6 involved revision and post-testing.

5. Results

The analysis and interpretation of the results were carried out according to the stated null hypotheses as follows:

H_{01}: There is no significant difference in the Biology drawing proficiency of students taught Biology using Model-Based Learning and those taught using the conventional teaching method in secondary schools of Birnin Kebbi Education Zone, Kebbi State, Nigeria**.**

***Table** 1:* Independent Samples t-test of Biology Drawing Proficiency of Students Taught Using Model-Based Learning and Conventional Teaching Method

GROUP	N	Mean	SD	Df	T	p-value	Decision
Model-based Learning (MBL)	111	60.3514	6.54029	206	1.582	.036	Rejected
Conventional	97	58.8763	6.89846				

Source: Field Work, 2025 α- value= 0.05

From the above table, the independent samples t-test revealed a statistically significant difference in Biology drawing proficiency between students taught Biology using Model-Based Learning and those taught using the conventional teaching method, t (206) = 1.582, p = .036. Since the p-value (.036) is less than the 0.05 level of significance, the null hypothesis is rejected. Therefore, it was concluded that Model-Based Learning significantly improved students' Biology drawing proficiency in Biology compared with the conventional teaching method.

H$_{02}$: There is no significant difference in the Biology drawing proficiency of male and female students taught Biology using Model-Based Learning in secondary schools of Birnin Kebbi Education Zone, Kebbi State, Nigeria.

***Table 2*:** Independent Samples t-test of Biology Drawing Proficiency of Male and Female Students in the Experimental Group

GROUP	Gender	N	Mean	SD	Df	T	p-value	Decision
Experimental Group	Male	55	60.7273	7.32437	109	11.339	.001	Rejected
	Female	56	53.2321	3.75616				

Source: Field Work, 2025 α- value= 0.05

The independent samples t-test revealed a statistically significant difference in the drawing proficiency of male and female students taught Biology using Model-Based Learning, t(109) = 11.339, p < .05. Since the p-value (0.001) is less than the 0.05 level of significance, the null hypothesis is rejected. This implies that there is a statistically significant difference in the academic performance of male and female students taught Biology using Model-Based Learning, with male students obtaining significantly higher mean in drawing proficiency scores than female students.

6. Discussion of Findings

The findings of the study revealed that students taught Biology using Model-Based Learning (MBL) demonstrated significantly higher drawing proficiency than those taught using the conventional teaching method. Students in the experimental group obtained a higher mean score (M = 60.35, SD = 6.54) than those in the control group (M = 58.88, SD = 6.90), and the difference was statistically significant, t(206) = 1.582, p = .036. This finding suggests that MBL was effective in developing students' ability to observe, interpret, and accurately represent biological structures. The finding is consistent with Carroll and Park (2024), who reported that model-based instructional strategies can support students' visualization, conceptual reasoning, and active engagement with scientific representations. Similarly, Wilson et al. (2020) emphasized that modelling makes relationships and systems visible to learners, thereby supporting the construction and interpretation of scientific representations. Shapiro et al. (2020) further demonstrated that focused observation and drawing activities can enhance students' three-dimensional spatial understanding. The improvement observed in the present study may therefore be attributed to students' repeated opportunities to examine biological models from different perspectives before translating their observations into two-dimensional biological drawings. Thus, the findings provide empirical support for the use of MBL as an instructional approach for developing drawing proficiency in Biology.

The effectiveness of MBL may be explained by the active and collaborative experiences embedded in the approach. Students observed models, discussed structures, and constructed representations, while modelling research shows positive effects on scientific reasoning and content understanding (Malone & Schuchardt, 2023). The combination of visualization, discussion, feedback, and drawing practice may therefore have provided richer learning experiences than conventional instruction.

The study also revealed a statistically significant difference in the drawing proficiency of male and female students exposed to MBL, with male students recording a higher mean score than their female counterparts. This finding indicates that gender differences were observed in drawing proficiency under the conditions of the present study. However, the result should not be interpreted to mean that gender inherently determines students' ability to produce biological drawings. Differences in prior learning experiences, opportunities for practical engagement, confidence, and participation may contribute to variations in performance. This interpretation is particularly important because Chinyere and Bebia (2020), in their study of Biology students in Cross River State, Nigeria, reported that gender had no significant effect on students' achievement following practical drawing instruction. The difference between their findings and those of the present study may be related to differences in instructional approach, study context, outcome measures, or participants. Ejezube et al. (2025) similarly emphasized the importance of learning experiences and practical engagement in students' science-related skills, while Monday and Patrick (2026) suggested that learner-centred instructional approaches can help reduce gender disparities in learning outcomes. Therefore, the gender finding in the present study suggests the need for teachers to ensure equitable participation and provide both male and female students with comparable opportunities to observe, manipulate, discuss, and draw biological models.

Overall, the findings extend previous research by suggesting that MBL can contribute not only to conceptual understanding and scientific reasoning but also to the practical competency of biological drawing. This is relevant in Nigeria, where weaknesses in titling, magnification, and adherence to drawing conventions have been documented (Ebere & Abugu, 2025).

7. Conclusion

The study concludes that Model-Based Learning is a more effective instructional strategy than the conventional teaching method in improving Biology drawing proficiency among secondary school students in Birnin Kebbi Educational Zone, Kebbi State. The findings revealed that students exposed to Model-Based Learning demonstrated greater improvement in their ability to construct, label, and interpret biological diagrams. Additionally, the study established that gender has a significant influence on students' drawing proficiency, with male students showing higher performance than their female counterparts. Overall, the results highlight the importance of adopting learner-centered instructional approaches, such as Model-Based Learning, to enhance students' understanding, engagement, and performance in Biology.

8. Recommendation

i. Biology teachers should adopt Model-Based Learning (MBL) as an instructional strategy, particularly when teaching topics that require students to observe, construct, label, and interpret biological structures. Teachers should provide students with opportunities to examine models from different perspectives before producing biological drawings.

ii. Schools should provide adequate biological models and other instructional resources such as charts, specimens, three-dimensional models, and visual materials to support the effective implementation of Model-Based Learning. The availability of these resources will enable students to develop their observation, visualization, and drawing proficiency.

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