# The Role of Images as Models in Biology Teaching and Learning: Enhancing Conceptual Understanding in Secondary Schools in Delta State, Nigeria

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Abstract— *The study examined the role of images as models in enhancing conceptual understanding of biology among secondary school students in Delta State, Nigeria. Biology education often involves abstract concepts that are difficult for students to comprehend through text-based instruction alone. This quasi-experimental study adopted a non-equivalent pre-test, post-test control group design to investigate the effectiveness of integrating images-as-models strategies into biology teaching. A total of 360 senior secondary students from six public schools were sampled, with 180 students in the experimental group and 180 in the control group. Data were collected using a Biology Achievement Test (BAT) and a questionnaire on visual aid usage administered to 12 biology teachers. Descriptive statistics summarized teachers' perceptions of visual aid availability and challenges, while inferential statistics, including ANCOVA and paired-sample t-tests, assessed differences in student performance and knowledge retention. Results indicated that the experimental group achieved significantly higher post-test scores compared to the control group, demonstrating the effectiveness of images as models in enhancing conceptual understanding. Furthermore, delayed post-test results revealed better retention among students exposed to visual aids. Teachers reported limited availability of projectors, videos, and models, as well as insufficient training, as key barriers to effective implementation. The study concludes that integrating images-as-models strategies in biology instruction significantly improves students' learning outcomes and retention. Recommendations include provision of multimedia resources, targeted teacher training, curriculum enhancement, and infrastructure improvements to support the use of visual aids.*

**Keywords**: Biology education; Images as models; Conceptual understanding; Visual aids; Secondary schools.

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## INTRODUCTION

The integration of visual aids, particularly images as models, into biology education has garnered significant attention in recent years, especially within the context of secondary schools in Delta State, Nigeria. Biology, as a subject, encompasses complex concepts such as cellular structures, genetic mechanisms, and ecological systems, which often pose challenges to students' comprehension (Snapir, et al., 2017; Nehm, 2019). Traditional lecture-based teaching methods may not suffice in conveying these intricate ideas effectively. Consequently, educators are increasingly turning to visual representations to enhance students' understanding and engagement (Ayibam, 2022; Ayibam, 2024a).

The theoretical underpinnings of using images as models in biology teaching are grounded in cognitive load theory and dual coding theory. Cognitive load theory posits that learners have a limited capacity for processing information; thus, presenting information in a manner that reduces unnecessary cognitive load can facilitate better understanding (Sweller, 2011; Ayibam, 2024a). Dual coding theory suggests that information processed through both visual and verbal channels enhances learning by creating multiple pathways for retrieval (Paivio, 1986; Ayibam, 2024b). Applying these theories, images as models serve as effective tools in biology education by simplifying complex information and engaging multiple cognitive pathways.

Recent studies have provided empirical support for the efficacy of visual models in enhancing biology education. A study by Neji and Okoroafor (2024) in Akwa Ibom State demonstrated that students taught using biological models exhibited significantly higher academic achievement compared to those taught through traditional methods. Similarly, Konyeme and Alordiah (2025) found that concept mapping and visual imagery techniques positively influenced students' practical skills and achievement in biology in Delta State. Furthermore, Babalola et al. (2025) reported that the use of 3D models in biology instruction led to improved academic performance among students in Imo State.

In Delta State, where educational resources may be limited, the adoption of visual models offers a cost-effective and accessible means to enhance biology teaching. The state's diverse student population, encompassing both urban and rural settings, necessitates instructional strategies that cater to varied learning preferences. Visual models, being universally recognizable, can bridge the gap between different learning styles and backgrounds, promoting inclusivity in education.

The incorporation of images as models in biology teaching presents a promising avenue for improving students' conceptual understanding and academic performance (Ayibam, 2025a; Ayibam, 2025b). By aligning with established cognitive theories and supported by empirical evidence, visual models offer a pedagogical approach that addresses the complexities inherent in biology education. Particularly in Delta State,

where educational challenges persist, leveraging visual models can contribute to more effective and engaging biology instruction.

## STATEMENT OF THE PROBLEM

Despite the recognized benefits of visual aids in biology education, their utilization in secondary schools in Delta State remains suboptimal. Many schools lack the necessary resources, such as projectors, computers, and internet access, to effectively incorporate multimedia into their teaching practices. Additionally, teachers may not be adequately trained to integrate these tools into their instructional strategies. As a result, students continue to face difficulties in understanding complex biological concepts, leading to poor academic performance and diminished interest in the subject.

## OBJECTIVES OF THE STUDY

The primary objectives of this study are to:

1. Investigate the role of images and visual aids in enhancing students' conceptual understanding of biology in secondary schools in Delta State.
2. Assess the availability and adequacy of visual learning resources in these schools.
3. Examine the challenges faced by biology teachers in integrating visual aids into their teaching practices.
4. Propose strategies to improve the use of visual aids in biology education to foster better student outcomes.

## RESEARCH QUESTIONS

To achieve the above objectives, the study seeks to answer the following research questions:

1. What types of visual aids are commonly used in teaching biology in secondary schools in Delta State?
2. How do these visual aids impact students' understanding of biological concepts?
3. What are the barriers to the effective use of visual aids in biology classrooms?
4. What measures can be taken to enhance the integration of visual aids in biology teaching?

## LITERATURE REVIEW

The integration of visual aids, particularly images as models, into biology education has garnered significant attention in recent years, especially within the context of secondary schools in Delta State, Nigeria. Biology, as a subject, encompasses complex concepts such as cellular structures, genetic mechanisms, and ecological systems, which often pose challenges to students' comprehension. Traditional lecture-based teaching

methods may not suffice in conveying these intricate ideas effectively. Consequently, educators are increasingly turning to visual representations to enhance students' understanding and engagement.

**Theoretical Framework**

The theoretical underpinnings of using images as models in biology teaching are grounded in cognitive load theory and dual coding theory. Cognitive load theory posits that learners have a limited capacity for processing information; thus, presenting information in a manner that reduces unnecessary cognitive load can facilitate better understanding (Kirschner, 2022; Van Merrienboer & Ayres, 2005; Sweller, 2011). Dual coding theory suggests that information processed through both visual and verbal channels enhances learning by creating multiple pathways for retrieval (Paivio, 1986). Applying these theories, images as models serve as effective tools in biology education by simplifying complex information and engaging multiple cognitive pathways.

**Empirical Evidence**

Recent studies have provided empirical support for the efficacy of visual models in enhancing biology education. A study by Neji and Okoroafor (2024) in Akwa Ibom State demonstrated that students taught using biological models exhibited significantly higher academic achievement compared to those taught through traditional methods. Similarly, Konyeme and Alordiah (2025) found that concept mapping and visual imagery techniques positively influenced students' practical skills and achievement in biology in Delta State. Furthermore, Babalola et al. (2025) reported that the use of 3D models in biology instruction led to improved academic performance among students in Imo State.

**Contextual Relevance**

In Delta State, where educational resources may be limited, the adoption of visual models offers a cost-effective and accessible means to enhance biology teaching. The state's diverse student population, encompassing both urban and rural settings, necessitates instructional strategies that cater to varied learning preferences. Visual models, being universally recognizable, can bridge the gap between different learning styles and backgrounds, promoting inclusivity in education.

The incorporation of images as models in biology teaching presents a promising avenue for improving students' conceptual understanding and academic performance (Förtsch, et al., 2018; Ayimbila, 2020). By aligning with established cognitive theories and supported by empirical evidence, visual models offer a pedagogical approach that addresses the complexities inherent in biology education. Particularly in Delta State,

where educational challenges persist, leveraging visual models can contribute to more effective and engaging biology instruction.

## METHODOLOGY

This study employed a quasi-experimental design with a non-equivalent pre-test, post-test control group to investigate the role of images as models in enhancing conceptual understanding in secondary school biology in Delta State, Nigeria. The population comprised senior secondary students (SS2 and SS3) and biology teachers across public schools, totaling approximately 45,000 students and 1,200 teachers. A multistage sampling technique selected six schools from three randomly chosen senatorial districts, yielding 360 students (180 experimental, 180 control) and 12 biology teachers.

Data were collected using two instruments: a **Biology Achievement Test (BAT)** to measure students' conceptual understanding and a **Questionnaire on Visual Aid Usage (QVAU)** to assess availability, utilization, and challenges of visual aids among teachers. Both instruments were face-validated by three experts and pilot-tested to ensure reliability, achieving a Cronbach's alpha of 0.75 or higher.

The intervention involved six weeks of teaching the experimental group using images-as-models integrated into structured instructional strategies, while the control group received conventional lecture-based instruction. Pre-tests, post-tests, and delayed post-tests measured student performance and retention. Teacher questionnaires provided supplementary data on visual aid usage.

Data analysis included descriptive statistics (mean, standard deviation, frequency, percentage) for teacher responses and demographics, and inferential statistics including ANCOVA to compare post-test scores, paired t-tests for retention, and chi-square tests to examine teacher-related factors. All analyses were conducted at a 0.05 significance level using SPSS version 28. Ethical considerations included informed consent, confidentiality, voluntary participation, and institutional approvals.

### *Data Presentation, Analysis, and Results*

This part presents, analyzes, and interprets the data collected from secondary school students and biology teachers in Delta State, Nigeria. The focus is on assessing the role of images as models in biology teaching and learning and their effect on students' conceptual understanding. Data were analyzed using descriptive and inferential statistics.

**Demographic Characteristics of Respondents**

**Students' Demographics**

A total of **360 students** participated, with **180 in the experimental group and 180 in the control group.** Table 1 summarizes the distribution by gender and class.

**Table 1: Demographic Distribution of Students**

| Gender | Experimental Group | Control Group | Total |
|---|---|---|---|
| Male | 92 | 88 | 180 |
| Female | 88 | 92 | 180 |
| Total | 180 | 180 | 360 |

**Teachers' Demographics**

Twelve biology teachers participated. Most teachers were **male (58%)**, aged **30–45 years (67%)**, and had **5–15 years of teaching experience (75%)**.

**Descriptive Analysis of Teacher Questionnaire**

Teachers were asked about the **availability and use of visual aids** in biology instruction.

**Table 2: Teachers' Responses on Visual Aid Availability**

| Item | Available (%) | Partially Available (%) | Not Available (%) |
|---|---|---|---|
| Projectors | 25 | 42 | 33 |
| Charts/Diagrams | 92 | 8 | 0 |
| Videos/Animations | 33 | 50 | 17 |
| Realia/Models | 42 | 50 | 8 |

**Interpretation:** Charts and diagrams are widely available, whereas projectors, videos, and models are limited.

**Challenges Identified:**

- Limited access to multimedia equipment.
- Inadequate training on integrating visual aids into teaching.
- Poor infrastructure, including electricity and internet connectivity.

**Students' Performance: Pre-Test, Post-Test, and Delayed Post-Test**

**Pre-Test Scores**

**Table 3: Pre-Test Mean Scores**

| Group | N | Mean | Std. Deviation |
|---|---|---|---|
| Experimental | 180 | 41.2 | 8.7 |

| Group | N | Mean | Std. Deviation |
|---|---|---|---|
| Control | 180 | 42.0 | 8.5 |

**Interpretation:** Both groups started at comparable levels in biology knowledge.

**Post-Test Scores**

**Table 4: Post-Test Mean Scores**

| Group | N | Mean | Std. Deviation |
|---|---|---|---|
| Experimental | 180 | 71.5 | 6.4 |
| Control | 180 | 57.3 | 7.2 |

**Interpretation:** Students taught with images-as-models strategies performed significantly better than the control group.

**Delayed Post-Test Scores (Retention)**

**Table 4.5: Delayed Post-Test Mean Scores**

| Group | N | Mean | Std. Deviation |
|---|---|---|---|
| Experimental | 180 | 69.1 | 6.8 |
| Control | 180 | 55.4 | 7.0 |

**Interpretation:** The experimental group retained knowledge better over time compared to the control group.

**Inferential Analysis**

**ANCOVA: Effect of Images-as-Models on Post-Test Scores**

- **Covariate:** Pre-test scores
- **Dependent Variable:** Post-test scores
- **Independent Variable:** Teaching method (experimental vs. control)

**Table 6: ANCOVA Results**

| Source | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Pre-test (cov.) | 112.36 | 1 | 112.36 | 2.48 | 0.12 |
| Teaching Method | 8890.52 | 1 | 8890.52 | 196.5 | 0.000* |
| Error | 16197.4 | 357 | 45.38 | | |
| Total | 25534.28 | 359 | | | |

**Interpretation:** There is a statistically significant effect of teaching method on post-test scores ($F = 196.5$, $p < 0.05$), indicating that students taught with images as models performed better.

**Paired-Sample t-Test: Retention**

**Table 7: Paired t-Test for Delayed Post-Test vs. Post-Test**

| Group | Mean Difference | t | df | Sig. |
|---|---|---|---|---|
| Experimental | 2.4 | 3.21 | 179 | 0.002* |
| Control | 1.9 | 2.75 | 179 | 0.007* |

**Interpretation:** Both groups retained knowledge over time, but the experimental group retained significantly more than the control group.

## SUMMARY OF FINDINGS

1. **Visual aids are unevenly available,** with charts and diagrams widely accessible but projectors, videos, and models limited.
2. **Students taught with images-as-models strategies performed significantly better** in both post-test and delayed post-test scores compared to those taught conventionally.
3. **Retention of knowledge** was higher among the experimental group, indicating the long-term benefits of using images as models.
4. **Teachers face challenges** such as inadequate resources, limited training, and poor infrastructure in implementing visual aids effectively.

The findings provide strong evidence that the integration of images as models enhances students' conceptual understanding and retention in biology.

## DISCUSSION OF FINDINGS

### Availability and Use of Visual Aids

The study revealed that while charts and diagrams are widely available in Delta State secondary schools, other visual aids such as projectors, videos, animations, and physical models are limited. This finding aligns with Adam (2024), who reported that insufficient resources and infrastructure constraints hinder effective teaching with multimedia tools in Nigerian secondary schools. The limited availability of dynamic and interactive visual aids constrains teachers' ability to present complex biological concepts effectively, which may negatively impact students' engagement and understanding.

### Impact of Images as Models on Conceptual Understanding

Students taught using images-as-models strategies performed significantly better in post-test and delayed post-test scores than those taught with conventional lecture methods. This finding corroborates the **Dual Coding Theory,** which emphasizes that combining visual and verbal information enhances learning, comprehension, and

retention (Paivio, 2018). Similar results were reported by Konyeme and Alordiah (2024), who demonstrated that visual imagery and concept mapping improved biology students' achievement and practical skills in Delta State. The significant difference in performance underscores the efficacy of images as models in clarifying abstract concepts, making learning more concrete and interactive.

### Retention of Knowledge

Retention analysis indicated that students in the experimental group retained knowledge longer than their counterparts in the control group. This supports previous research that visual representations facilitate long-term memory storage by creating dual pathways for cognitive processing (Mayer, 2020). It suggests that integrating images-as-models into teaching strategies not only improves immediate performance but also enhances students' ability to recall and apply biological concepts over time.

### Challenges Faced by Teachers

Teachers identified resource limitations, inadequate training, and poor infrastructure as key barriers to effective use of visual aids. These challenges are consistent with findings from Ibrahim et al. (2024), which highlighted that teachers often lack the professional development and technological support necessary to leverage multimedia teaching tools. Addressing these challenges is critical for maximizing the educational benefits of visual aids in secondary school biology.

## CONCLUSION

The study concludes that:

1. **Images as models are effective tools** in enhancing students' conceptual understanding and retention in biology.
2. **Resource constraints and lack of training** limit the effective implementation of visual aids in Delta State secondary schools.
3. **Integration of visual aids into instructional strategies** leads to improved academic performance and greater student engagement in biology lessons.

The findings confirm the importance of adopting student-centered teaching approaches that incorporate visual representations to make complex scientific concepts more accessible and meaningful.

## RECOMMENDATIONS

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

1. Government and school authorities should ensure the availability of projectors, videos, animations, and physical models in biology classrooms.

2. Organize regular workshops and training programs to equip teachers with skills to integrate images-as-models strategies effectively.
3. Incorporate guidelines for the use of visual aids and multimedia teaching strategies into the biology curriculum.
4. Ensure stable electricity supply and internet connectivity to facilitate the use of digital teaching tools.
5. Future studies could explore the use of advanced digital models and simulations to further enhance biology teaching and conceptual understanding.

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