
CONCEPT MAPPING AND VISUAL IMAGERY TECHNIQUES AS DETERMINANTS OF SENIOR SECONDARY SCHOOL STUDENTS' ACHIEVEMENT AND PRACTICAL SKILLS IN BIOLOGY IN DELTA STATE, NIGERIA

Josephine Ese KONYEME
josephine.konyeme@unidel.edu.ng

&

Caroline Ochuko ALORDIAH
caroline.alordiah@unidel.edu.ng

Department of Science Education, University of Delta, Agbor, Nigeria

Abstract

This study used a pretest-posttest control group quasi-experimental design to evaluate the effects of concept mapping and visual imagery techniques on senior secondary school students' achievement and practical skills in Biology. It also explored gender and learning styles as moderating factors. The study involved six public high schools selected from three Senatorial Districts in Delta State, Nigeria, with intact senior secondary II biology classrooms. Randomization allocated the schools to three groups: concept mapping (46 students), visual imagery (38 students), and control (49 students). Data were collected using the Biology Achievement Test, the Students' Learning Style Questionnaire, and the Biology Practical Test. The intervention lasted six weeks, and analyses included covariance and post-hoc tests at a 0.05 significance level. Results showed that visual imagery techniques led to a significant improvement in academic performance, especially for female students and visual learners. The visual imagery group had the highest mean achievement score (16.70), followed by the concept mapping group (14.57) and the control group (9.47). Gender also influenced practical skills, with females scoring higher (23.47) than males (20.27). Learning styles affected achievement, with visual learners achieving the highest mean score (15.27), followed by tactile learners (14.32) and auditory learners (12.95). The findings suggest that integrating visual imagery and concept mapping techniques in the biology curriculum can improve student performance and skills, particularly for visual learners and female students.

Keywords: Concept mapping, Achievement in biology, Visual imagery technique, Biology achievement, Learning styles in biology

Introduction

In secondary biology education, students gain essential critical thinking, analytical reasoning, and inquiry skills (Jack, Danjuma, & Gbadamosi, 2018; Ekasari & Maulidina, 2023). Raymond (2010) emphasized that biology is a fundamental

scientific field focused on understanding the universe's basic elements, interactions, and outcomes, Biology's significance extends to technological advancement, reinforcing its relevance across modern disciplines. In Nigeria, secondary biology has been a core part of the curriculum since pre-

independence (Adeyemo, 2010), aiming to teach foundational biological literacy for practical life, prepare students for advanced studies, and cultivate scientific skills and problem-solving abilities necessary for technological applications (Ogunleye & Babajide, 2010; Okeke & Ukoh, 2020).

Biology is central to technological innovation and the foundation of many applied sciences. Through the principles of biology, advancements like integrated circuits, machinery, energy systems, telecommunications, and ICT have emerged. Nigerian universities further recognized biology as essential for entry into science and engineering programs (Jack, Danjuma, & Gbadamosi, 2018). Despite these contributions, biology performance among Delta State students has fluctuated, partly due to pedagogical and curriculum challenges, including extensive content, abstract concepts, and limited practical skills (Ukoh, 2013; Asubiojo, 2015).

Concept maps, defined by Ahmad (2018) as visual tools for organizing and representing ideas, help students develop cognitive structures by linking concepts hierarchically. Concept mapping aligns with Ausubel's Assimilation Theory, which suggests that meaningful learning occurs when new information is integrated with existing cognitive structures. As graphic organizers, concept maps begin with a central idea and branch into related sub topics, supporting students in visualizing and connecting knowledge (Ahmad, 2018). By fostering these connections, concept maps aid in critical thinking and problem-solving—core skills in biological sciences.

Previous studies show that concept mapping can enhance cognitive processes by promoting active learning, thereby

supporting students in visualizing and concretizing abstract concepts (John, 2016; Vintzileos & Ananth, 2010). It serves as a diagnostic tool, allowing teachers to gauge students' understanding and misconceptions. Research supports concept mapping as a method for encouraging self-regulation.

Traditional teaching methods like lecturing, while efficient for content delivery, tend to result in passive learning, which may not align with the constructivist and inquiry-based approaches necessary in science education (Kalmakis, 2016; Sims, 2015). The shift towards active learning, incorporating activities like concept mapping, discussion, and group work, has been shown to develop deeper understanding and retention (Nabors, 2018). The California Department of Education (2015) emphasized that a variety of instructional strategies are essential for effective teaching, encouraging teachers to adapt their methods to facilitate learning across diverse student needs and backgrounds.

By constructing mental images of biology concepts, these techniques can foster cognitive engagement and problem-solving abilities, essential for meaningful learning. Concept mapping and visual imagery have shown promise in improving academic outcomes, fostering curiosity, and helping students create mental models that concretize abstract biological principles.

This study further investigated the effect of concept mapping and visual imagery on biology performance and practical skills, examining the moderating role of gender and learning style on these outcomes. By evaluating the efficacy of these strategies, this research aimed to provide insights into

enhancing biology instruction in secondary schools, potentially influencing instructional practices that support diverse learner profiles and improve educational outcomes in scientific subjects.

Hypotheses

- Ho1: There is no significant difference in the effect of concept mapping and visual imagery strategies on Students' achievement in biology.
- Ho2: There is no significant difference in the effect of concept mapping and visual imagery strategies on Students' Practical skills in biology.
- Ho3: There is no significant effect of gender on Students' achievement in biology.
- Ho4: There is no significant effect of gender on Students' Practical skills in biology.
- Ho5: There is no significant effect of learning style on Students' achievement in biology

Methodology

Research Design

The study adopted a pretest-posttest control group quasi-experimental design.

Selection of Participants

Three Local Government Areas were randomly selected from the three senatorial districts that make up Delta State. Two schools were purposively selected from each local government making a total of six schools. Intact class of senior secondary school II students in each of the six schools were randomly assigned to each of the experimental and control groups.

Research Instruments

Biology Achievement Test (BAT)

The researchers developed the Biology Achievement Test (BAT) and contained 30 multiple-choice questions. Section A gathered students personal data, including gender, while Section B consisted of 30 multiple-choice items on topics such as mendelian principles, genetics, heredity, evolution, mitosis, meiosis, and enzyme action. Students were asked to circle the correct answer from options A to D. The reliability of the instrument was established using the Kuder-Richardson 20 (KR20) formula, which yielded a reliability coefficient of 0.75.

Table 1: Table of specification for Biology Achievement Test (PAT)

Topic	Achievement						Total
	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation	
Reproduction	(1) 21	-	(8) 1,2,11,12,13, 20,25, 26	(1) 10	-	-	10
Mendelian principles	(2) 5, 16	(1) 27	(1) 8	-	-	(1) 17	5
Heredity	-	-	(6) 3, 6, 14, 15, 19, 28	-	-	(1) 4	7
Mitosis and meiosis	(1) 9	-	(1) 24	-	-	-	2
Digestion	-	(1) 22	(4) 7, 23, 29, 30	-	-	(1) 18	6
Total	4	2	20	1	-	3	30

Biology Practical Test (PBT)

The PBT instrument contained two practical questions developed by the researchers. Section A of the instrument consisted of the personal data of the subjects. It sought to find information on personal data on gender. Section B consisted of two practical questions. The reliability indices were ascertained as 0.70.

Students' Learning Style Questionnaire (SLSQ)

Students' Learning Style Questionnaire (SLSQ) was adapted from modified Barsch's Learning Style Questionnaire. The SLSQ contains 24 items, to elicit proper response from the respondents. Students' responses were used to classify the students into any of

the three learning styles considered in this study, Auditory, Visual and Tactile. After the instrument was trial tested, Cronbach alpha was utilized to ascertain the reliability of the instrument which gave reliability index of 0.78.

Instructional Guide for Concept mapping Strategy

This was an instructional guide for research assistants who participated in the experimental group one. It contained the statement of topic, instructional objectives and the procedures expected to be adhered to by the teachers in teaching the lessons. The concepts taught using this guide were motions, momentum, elasticity, momentum, projectile and equilibrium.

Instructional Guide for Visual Imagery Strategy

This was an instructional guide containing the statement of topic, instructional objectives and the procedures expected to be followed by the teachers in teaching the lesson. The concepts taught using this guide are motions, momentum, elasticity, momentum, projectile and equilibrium. It consisted of various steps which the teacher followed when teaching.

Instructional Guide for Conventional method

The instructional guide contained items guiding the conventional method of teaching by the teacher (i.e. the control group). It contained steps guiding the conventional strategy of teaching. This instructional guide contained the statement

of topic, objectives, instructional materials and the procedure followed by the teachers in teaching of biology topics in the classroom using the conventional teaching method. The reliability coefficient was obtained using inter-rater Scott's pi.

Method of Data Analysis

The collected data were analysed utilizing descriptive statistics (mean, percentage, standard deviation). Also, inferential statistics such as Analysis of covariance (ANCOVA) were utilized to determine the significant main.

RESULTS

Ho1: There is no significant difference in the effect of concept mapping and visual imagery strategies on Students' achievement in biology

Table 2: Analysis of Covariance (ANCOVA) of Post-Achievement by Treatment, Gender and Learning Styles

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1355.761	17	79.751	5.104	0.000	0.430
Intercept	1832.675	1	1832.675	117.280	0.000	0.505
Pre-achievement	106.628	1	106.628	6.824	0.010	0.056
Treatment	485.200	2	242.600	15.525	0.000*	0.213
Gender	10.604	1	10.604	0.679	0.412	0.006
Learning style	107.512	2	53.756	3.440	0.035*	0.056
Treatment x Gender	26.765	2	13.383	0.856	0.427	0.015
Treatment x Learning style	34.192	4	8.548	0.547	0.702	0.019
Gender x Learning style	9.968	2	4.984	0.319	0.728	0.006
Treatment x Gender x Learning style	53.912	4	13.478	1.150	0.332	0.029
Error	1797.051	115	15.627			
Total	26496.000	133				
Corrected Total	3152.812	132				

R Squared = 0.43 (Adjusted R Squared = 0.35) * denotes significant p<0.05

Table 2 revealed that there was a significant effect of treatment on students' achievement in biology ($F_{(2,131)} = 15.53$; $p < 0.05$, partial $\eta^2 = 0.21$). Therefore, the hypothesis was not accepted. To explore the magnitude of the

significant effect across treatment groups, the estimated marginal means of the treatment groups was carried out and the result is presented in Table 3.

Table 3: Estimated Marginal Means for Post-Achievement by Treatment and Control groups

Treatment	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
Concept mapping technique	14.57	0.95	12.69	16.44
Visual imagery technique	17.70	0.84	16.03	19.37
Conventional Strategy (CS)	9.47	0.97	7.55	11.40

Table 3 revealed that students exposed to Visual imagery technique treatment group 2 had highest adjusted mean score in their post-achievement in biology (17.70) followed by those taught by the Concept mapping technique treatment group 1 (14.57) and the Conventional Strategy (CS)

control group (9.47). To determine which of the groups caused this significant effect of treatment on students' achievement in biology, the Bonferroni post-hoc test was carried out across the groups, while the result is presented in Table 4.

Table 4: Bonferroni Post-hoc Analysis of Post-Achievement by Treatment and Control Groups

(I) Treatment	(J) Treatment	Mean Difference (I-J)	Sig.
Concept mapping technique	Visual imagery technique	-3.131*	.046
	Conventional Strategy (CS)	5.091*	.001
Visual imagery technique	Concept mapping technique	3.131*	.046
	Conventional Strategy (CS)	8.222*	.000
Conventional Strategy (CS)	Concept mapping technique	-5.091*	.001
	Visual imagery technique	-8.222*	.000

Table 4 indicated that students' post-achievement mean scores in biology in the Visual imagery technique was significantly different from those taught by Concept Mapping-based (CMbS) and Conventional (CS) strategies, respectively. This implies that the significant difference indicated by the ANCOVA result was due to the difference between the treatment groups

(visual imagery and concept mapping-based strategies) and also between the treatment and the control groups.

Ho2: There is no significant difference in the effect of concept mapping and visual imagery strategies on Students' Practical skills in biology

Table 5: Analysis of Covariance (ANCOVA) of Post-Practical skills by Treatment, Gender and Learning Styles

Source	Type III Sum of Squares	df	MS	F	Sig.	Partial Eta Squared
Corrected Model	654.121	17	38.478	1.743	0.045	0.205
Intercept	2092.042	1	2092.04	94.763	0.000	0.452
Pre-Practical skills	83.694	1	83.694	3.791	0.054	0.032
Treatment	45.432	2	22.716	1.029	0.361	0.018
Gender	146.294	1	146.294	6.627	0.011*	0.054
Learning style	45.421	2	22.711	1.029	0.361	0.018
Treatment x Gender	50.999	2	25.500	1.155	0.319	0.020
Treatment x Learning style	23.482	4	5.870	0.266	0.899	0.009
Gender x Learning style	62.507	2	31.253	1.416	0.247	0.024
Treatment x Gender x Learning style	39.311	4	9.828	0.594	0.620	0.015
Error	2538.812	115	22.077			
Total	70232.000	133				
Corrected Total	3192.932	132				

R Squared = 0.21 (Adjusted R Squared = 0.09) * denotes significant $p < 0.05$

Table 5 showed that the effect of treatment on students' practical skills in biology was not significant ($F_{(2, 131)} = 1.03$; $p > 0.05$, partial $\eta^2 = 0.02$). Hence, hypothesis which was not rejected. This mean that treatment had no effect on students' practical skills in biology.

Although, there was no significant difference across treatment groups, the estimated marginal means of the treatment groups was carried out in order to establish the performance across the groups and the result is presented in Table 6

Table 6: Estimated Marginal Means for Post-Practical Skills by Treatment and Control Group

Treatment	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Concept mapping technique	20.82	1.19	18.46	23.17
Visual imagery technique	22.95	1.09	20.79	25.11
Conventional Strategy (CS)	22.17	1.27	19.65	24.69

Table 6 revealed that students exposed to the Visual imagery technique treatment group had highest adjusted post-practical skills mean score in biology (22.95) followed by Conventional Strategy (CS) control group

(22.17) and Concept mapping technique treatment group (20.82). This difference is not statistically significant.

Ho3: There is no significant effect of gender on students' achievement in biology

There was no significant effect of gender on students' achievement in biology ($F_{(1, 132)} = 0.68$; $p > 0.05$, partial $\eta^2 = 0.01$). Therefore, hypothesis which was not rejected. This means that students' gender had no effect on their achievement in biology.

Ho4: There is no significant effect of gender on students' practical skills in biology

Table 2 showed that the effect of gender on students' practical skills in biology ($F_{(1, 132)} = 6.63$; $p < 0.05$, partial $\eta^2 = 0.05$) was

significant. Table 3.4 which showed the effect size of 5.0%, this means that 5.0% of the total variation in students' post-practical skills scores in biology in this ANCOVA model was as a result of the significant effect of gender on students' practical skills in biology. Hence, hypothesis was rejected. In order to determine the extent of the significant effect across gender, the estimated marginal means of gender group was carried out and the result is presented in Table 7.

Table 7: Estimated Marginal Means for Post-Practical Skills by Gender

Gender	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Male	20.27	0.97	18.36	22.19
Female	23.47	0.84	21.81	25.14

Table 7 revealed that female students had the higher adjusted post-practical skills mean score in biology (23.47) followed by their male counterparts (20.27). This difference is statistically significant.

Ho5: There is no significant effect of learning styles on students' achievement in biology

Table 2 indicated that there was a significant effect of learning styles on students'

achievement in biology ($F_{(2, 131)} = 3.44$; $p < 0.05$, partial $\eta^2 = 0.06$). It revealed an effect size of 6.0%, this implies that 6.0% of the total variation in students' post-achievement scores in biology was due to the significant effect of the learning styles on students' achievement in biology. Hence, hypothesis 5 was rejected.

Table 8: Estimated Marginal Means for Post-Achievement by Learning Styles

Learning Styles	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
Visual	15.27	0.66	13.97	16.57
Auditory	12.95	0.61	11.74	14.16
Tactile	14.32	1.45	11.45	17.19

Table 8 indicated that visual learning style students had the highest adjusted mean score in their post-achievement in biology (15.27) followed by tactile learning style (14.32) and auditory learning style (12.95). To determine which of the groups caused this

significant effect of learning styles on students' achievement in biology, the Bonferroni post-hoc test was carried out across the groups, while the result is presented in Table 9

Table 9: Bonferroni Post-hoc Analysis of Post-Achievement by Learning styles

(I) Learning styles	(J) Learning styles	Mean Difference (I-J)	Sig.
Visual	Auditory	2.321*	0.033
	Tactile	0.952	1.000
Auditory	Visual	-2.321*	0.033
	Tactile	-1.369	1.000
Tactile	Visual	-0.952	1.000
	Auditory	1.369	1.000

Table 9 revealed that the visual learning style students' post-achievement mean score in biology was not significantly different from their counterparts with tactile learning style but was significantly different from those with auditory learning styles. Table 9 also revealed that the difference in the post-achievement mean scores of tactile learning style students were not significantly different from those with auditory learning style. This means that the significant difference in students' post-achievement scores observed in the ANCOVA result was due to the difference between the visual and auditory learning styles.

Discussion of Findings

The results of hypothesis one indicated that there was a significant difference in the effect of concept mapping and visual imagery strategies on students' achievement in biology. The efficacy of both strategies was attributed to their ability to engage students actively in the learning process. This is in line with Syamsu et al. (2020), who emphasized the importance of using diverse stimuli to help students encode and recall information more effectively. Visual imagery, in particular, proved effective as it encouraged students to form mental pictures during the learning process, facilitating

better understanding and retention. This finding is consistent with studies by Syamsu et al. (2020) and Küssner and Eerola (2019), which highlighted the role of visual imagery in cognitive processes. Furthermore, visual imagery supports better memory retention, as indicated by Nemati (2009) and Zahedi and Abdi (2012), who showed that memory strategies like visual imagery can improve learning outcomes. The results underscore the importance of integrating visual-based teaching strategies in the biology curriculum to boost student performance.

The results of hypothesis two revealed that the effect of treatment on students' practical skills in biology was not statistically significant. Although students exposed to the visual imagery strategy had the highest adjusted mean score for practical skills, this difference was not significant when compared to the concept mapping and control groups. Studies such as Buzan (2020) and D'Antoni & Thomas (2022) have shown that concept maps are more effective in cognitive learning, aiding memory and comprehension but not necessarily fostering practical skill development. This limitation can be attributed to the fact that concept mapping does not focus on skill-based, hands-on learning, which is crucial for developing practical skills in fields like

biology. Visual imagery, though effective in supporting cognitive learning, also did not significantly affect practical skills. The study suggests that the nature of practical skills, which requires manual manipulation and hands-on experience, may not be directly influenced by these strategies. This indicates that while these cognitive strategies may enhance understanding and recall, they do not replace the need for direct engagement in practical, laboratory-based activities.

The result of hypothesis three revealed that gender did not have a significant effect on students' achievement in biology. These results support previous studies by Agommuoh and Nzewi (2003), Arigbabu and Mji (2014), and Ogunleye and Babajide (2011), which also found no significant gender difference in achievement in science and mathematics. However, this finding contradicts the results of Sabatinelli et al. (2014), which suggested that gender differences in the brain's visual cortex may influence how students visualize concepts, potentially affecting achievement.

The result of hypothesis four revealed that gender had a significant effect on students' practical skills in biology, with female students outperforming their male counterparts. This finding aligns with Sabatinelli et al. (2014), which suggests that gender differences in the visual cortex may influence how students visualize concepts, potentially enhancing females' acquisition of practical skills. This is further supported by Njoku (2022), who found that gender influenced practical skills development in biology, with females performing better in some contexts. However, this finding contradicts the results of Adeoye (2020) and Raimi (2022), who reported that male

students performed better in practical skills. The significant effect of gender on practical skills suggests that female students may possess an advantage in tasks requiring precision or attention to detail.

The result of hypothesis five indicated that learning styles significantly influenced students' achievement in biology. Visual learners showed the highest achievement scores, followed by tactile learners and auditory learners. This suggests that students perform better when instructional methods align with their preferred learning styles, as students can better understand and retain information when teaching methods match their cognitive preferences. This finding is consistent with studies by Ha (2021) and Senol and Ayham (2012), which highlighted the positive correlation between learning styles and academic performance.

Conclusion

In summary, the findings of this study reveal that both visual imagery and concept mapping strategies can significantly improve students' achievement in biology compared to conventional teaching methods. However, while these strategies enhanced cognitive learning, they did not significantly affect practical skills, which require more hands-on, kinesthetic learning experiences. Gender had no significant effect on students' achievement but did influence practical skills, with female students performing better. Additionally, learning styles had a significant impact on achievement, with visual learners benefiting the most from the instructional strategies used.

The study highlights the importance of incorporating visual and cognitive strategies into biology instruction while also

recognizing the need for practical, hands-on learning experiences. Teachers should adapt their methods to accommodate diverse learning styles and provide equitable opportunities for all students, regardless of gender. Future research could explore how to combine cognitive strategies like visual imagery and concept mapping with more practical, kinesthetic learning approaches to enhance both academic performance and practical skills in biology.

Recommendations

In light of the findings of this study, the following recommendations are therefore made:

- (i) Teachers should employ concept mapping-based and visual imagery strategies in the teaching of mechanics in biology in order to improve learners' achievement in biology.
- (ii) Parents and teachers should put the

learning styles of the learners into consideration in order to improve their achievement in biology.

- (iii) Curriculum planners could also gain by emphasizing that whenever the concept mapping-based and visual imagery strategies are to be utilized, there should be incorporation of activities that will translate what forms in the mind of learners into practice.
- (iv) Government should organise training and re-training programmes for in-service teachers on the effective utilization of concept mapping-based and visual imagery strategies through the organization of seminars, workshops and conferences for biology teachers in secondary school levels. This would help them to effectively and adequately employ these strategies in teaching biology.

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