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Enhancing Ecological Understanding: The Impact of Concept Mapping on Secondary Schools Students' Achievement in Ecology in Katsina State, Nigeria

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Abstract

This quasi-experimental study investigated the effect of a concept mapping instructional strategy on the attitude and academic achievement of senior secondary Biology students in Ecology in Katsina State, Nigeria. Employing a pre-test, post-test design, a sample of 142 SSII students from two public co-educational schools was purposively assigned to experimental (concept mapping, n = 80) and control (traditional lecture, n = 62) groups. Data were collected using a validated 30-item Ecology Achievement Test (EAT) with reliability coefficients of 0.84. Analysis using independent t-tests at α=0.05 revealed that students in the experimental group achieved significantly higher post-test scores (M = 41.56, SD = 8.09) than the control group (M = 28.00, SD = 6.49), t (140) = 21.967, p = .000. Furthermore, no significant gender-based differences were found in achievement t (78) = 23.457, p = .946) within the experimental group. The results highlight the pedagogical value of concept mapping in promoting meaningful learning towards Biology. It is recommended that this strategy be integrated into science teacher training and curriculum development.

Keywords*:* Academic Achievement, Biology Education, Concept Mapping, Ecology, Instructional Strategy

Introduction

Scientific and technological advancement is a cornerstone of modern national development, with a nation's prestige often linked to its scientific activities (Ezeh, 2006; Federal Ministry of Science and Technology [FMST], 2021)). In recognition of this, the Nigerian National Policy on Education prioritizes science education at all levels (Federal Republic of Nigeria [FRN], 2014; Nigerian Educational Research and Development Council [NERDC], 2020). Biology, as a fundamental science, provides essential knowledge applied in fields such as medicine, agriculture, and environmental management (Ndu et al., 2010; Walter, 2015; Okafor & Eze, 2022). Ecology, a core branch of Biology, is crucial for understanding environmental interrelationships and maintaining ecosystem health. Consequently, fostering a deep conceptual understanding of ecological principles is vital for sustainable development and scientific literacy.

Despite its importance, student academic performance in Biology, particularly in Ecology, remains a persistent concern in Nigeria, as evidenced by consistently high failure rates in national examinations (Kyado et al., 2019; Nja et al., 2022; West African Examinations Council [WAEC], 2023). Researchers attribute this underachievement largely to prevalent, ineffective teacher-centred instructional methods. The exclusive use of traditional lecture and "chalk-and-talk" approaches is critiqued for promoting rote memorization at the expense of genuine conceptual understanding (Agogo & Onda, 2014; Opara, 2009; Eze & Oladejo, 2023). These passive learning environments often fail to facilitate the cognitive integration necessary for mastering complex ecological topics.

In response, constructivist-based strategies like concept mapping are advocated as pedagogical alternatives. Concept mapping is a graphical tool that organizes and visually represents knowledge by illustrating relationships between concepts using nodes and linking phrases (Ajaja, 2007; Novak & Cañas, 2008). It facilitates meaningful learning by helping students actively integrate new information with prior knowledge, thereby strengthening cognitive structures and improving content retention (Novak, 1998; Amoke et al., 2023). Contemporary studies suggest that concept mapping can enhance academic achievement in science education (Sakiyo & Waziri, 2015; Ibrahim & Abdullahi, 2021; Bello & Yusuf, 2024). However, findings regarding its

interaction with gender on academic outcomes have been inconsistent, necessitating further contextual investigation (Akintola, 2017; Mohammed & Adeoye, 2022).

Given the persistent deficit in academic performance in Biology and the limited localized research on innovative instructional strategies for teaching Ecology, this investigation was warranted. Therefore, this study focused on examining the effect of a concept mapping instructional strategy on the academic achievement of senior secondary school students in Ecology, while also exploring potential gender differences in its effectiveness.

Statement of the Problem

The persistent reliance on traditional, expository teaching methods in Nigerian Biology classrooms continues to be a major factor contributing to students' poor academic performance and lack of conceptual depth, particularly in demanding areas such as Ecology (WAEC Chief Examiners Reports, 2016-2022; Nja et al., 2022). These teacher-centered approaches often fail to foster active engagement, critical thinking, and the meaningful integration of knowledge required to master complex ecological interdependencies (Agbi et al., 2023; Eze & Ezenandu, 2022). In response, learner-centered, constructivist strategies like concept mapping have gained recognition for their potential to promote meaningful learning and improve outcomes in science education (Olagbaju & Oludipe, 2020; Ibe & Kalu, 2022).

However, despite evidence of its efficacy in broader contexts, there is a notable scarcity of localized, empirical research investigating the specific impact of concept mapping on academic achievement in Ecology within the unique educational setting of Dutsin-Ma, Katsina State. Furthermore, while equitable pedagogy is a critical concern, findings on whether concept mapping differentially benefits male and female students remain inconsistent and require context-specific validation (Amosa et al., 2021; Yusuf & Afolabi, 2020). This study, therefore, aims to address these gaps by empirically determining the comparative effectiveness of the concept mapping strategy against the conventional lecture method in enhancing students' academic achievement in Ecology, and by examining whether its effects are moderated by gender.

Objectives of the Study

The main objective was to determine the effects of a concept mapping instructional strategy on attitude and achievement in Ecology among SSII students. The specific objectives were to:

i. Compare the academic achievement in Ecology of students taught using concept mapping versus the lecture method.

ii. Examine the difference in academic achievement between male and female students taught Ecology using concept mapping.

Research Questions

The following research questions were raised to guide the study:

i. What is the difference in mean achievement scores between students taught Ecology with concept mapping and those taught with the lecture method?

ii. What is the difference in mean achievement scores between male and female students taught Ecology using concept mapping?

Hypotheses

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

$H0_1$: There is no significant difference in the mean achievement scores of students taught Ecology with concept mapping and those taught with the lecture method.

$H0_2$: There is no significant difference in the mean achievement scores of male and female students taught Ecology using concept mapping.

Methodology

This study employed a quasi-experimental pre-test, post-test control group design, utilizing intact classes to avoid disrupting school schedules, a suitable approach when random assignment is not feasible (Nwankwo, 2007). The population comprised all 803 SSII Biology students from twelve public senior secondary schools in the Dutsin-Ma zone. A purposive sample of 142 students

from two co-educational schools was selected, with one school randomly assigned as the experimental group (n = 80) and the other as the control group (n = 62). A validated instruments was used for data collection: a 30-item multiple-choice Ecology Achievement Test (EAT), which demonstrated high reliability coefficients of 0.84. Following a pre-test administration of both instruments, the experimental group was taught selected Ecology topics (e.g., ecosystem components, basic ecological concepts) using the concept mapping instructional strategy over six weeks, while the control group covered the same content using the conventional lecture method. A post-test was then administered to both groups. Data were analyzed using descriptive statistics (mean, standard deviation) to answer the research questions, and inferential statistics, specifically an independent t-test, were used to test the hypotheses at a 0.05 significance level.

Results

The results were presented in line with the stated research questions and hypotheses; the results were interpreted at the $p < 0.05$ level of significance.

Answers to Research Questions

Research Question One: What is the difference in the mean achievement between senior secondary school students taught ecology using concept mapping and those taught using lecture method?

Table 1: Mean and Standard Deviation of Students of Experimental and Control Groups

Group	N	Pre-test		Post-test		Mean difference
		M	SD	M	SD	
Experimental	80	28.91	9.13	41.56	8.09	13.56
Control	62	26.68	6.24	28.00	6.49	2.24

Descriptive statistics for pre-test and post-test achievement scores are presented in Table 1. The experimental group showed an increase from pre-test (M = 28.91, SD = 9.13) to post-test (M = 41.56, SD = 8.09), with a mean gain of 13.56. The control group demonstrated a smaller increase from pre-test (M = 26.68, SD = 6.24) to post-test (M = 28.00, SD = 6.49), with a mean gain of 2.24. This result indicates that the concept mapping instructional strategy had a positive effect on students' academic achievement in Ecology.

Research Question Two: What is the differences in the mean achievement scores between male and female students taught ecology using concept mapping?

To answer research question three, mean and standard deviations of performance scores were considered. The mean achievement scores of male and female students in experimental group were sorted according to gender and subjected to descriptive statistics analysis. Mean and standard deviation were computed and used to draw the Table 2

Table 2: Mean and Standard Deviation of Male and Female students in the Experimental Group

Gender	Group	N	Mean	Standard Deviation	Mean difference
Male	Exp.	45	22.850	3.340	0.050
Female	Exp.	35	22.800	3.480	

Table 2 show that male students in the experimental group (M = 22.85, SD = 3.34) and female students in the same group (M = 22.80, SD = 3.48) demonstrated nearly equivalent levels of academic achievement, with a negligible mean difference of 0.05. The small variability in scores, as indicated by the similar standard deviations, suggests no meaningful difference in academic achievement between male and female students taught Ecology using the concept mapping instructional strategy.

Hypotheses Testing

For the inferential analysis, Independent t-test, Paired t-test and Mann Whitney U-test statistics were used to test the null hypotheses at $P \leq 0.05$ level of significance.

H01: There is no significant difference between the Academic Achievement of students taught Ecology using concept mapping instructional strategy and their counterparts taught Ecology using conventional lecture method.

To test null hypothesis one, the academic achievement scores of students in experimental and control groups were subjected to Independent t- test statistic and summary of analysis are shown on Table 3

Table 3: Independent t-test Analysis of Mean Performance Scores of Experimental and Control Groups

Group	N	Mean	SD	Df	t-value	p-value	Decision
Experimental	80	21.840	3.390	140	21.967	.000	Ho is Rejected
Control	62	13.040	3.907				

Significant at α = P≤ 0.05

Table 3 reveals that An independent samples t-test revealed a statistically significant difference in post-test achievement scores between the experimental group (taught with concept mapping) and the control group (taught with the lecture method), t(140) = 21.97, p\ < .001. The experimental group (M = 41.56, SD = 8.09) significantly outperformed the control group (M = 28.00, SD = 6.49). Consequently, the null hypothesis was rejected, indicating that the concept mapping instructional strategy significantly enhanced students' achievement in Ecology concepts

H02: There is no significant difference between the Academic Achievement of Male and Female Students taught Ecology using Concept Mapping Instructional Strategy.

To test null hypothesis three, the academic achievement scores of male and female students in experimental group were subjected to Paired t-test statistics and summary of analysis are presented in the Table 4

Table 4: Paired t-test Analysis of Mean Performance Scores of male and female students in the Experimental group

Gender	N	Mean	SD	Df	t-value	p-value	Decision
Male	45	21.852	1.003	78	23.457	.946	Not Rejected
Female	35	21.801	1.376				

Not Significant at α = P≤ 0.05

As shown in Table 4, the independent samples t-test indicated no statistically significant difference in academic achievement scores between male and female students in the experimental group, t(78) = 23.457, p = .946. Since p > .05, the null hypothesis was retained, indicating that the concept mapping instructional strategy had an equivalent effect on the academic achievement of both male and female students. This suggests that the strategy is gender-inclusive in its impact on learning outcomes.

Summary to Findings

Based on the outcome of the analysis, the followings are the major findings of this study:

i. There is a significant difference between the academic achievement scores of students taught Ecology with concept mapping instructional strategy and those taught with conventional lecture method.

ii. There is no significant difference between academic performance scores of male and female students taught Ecology with concept mapping instructional strategy.

Discussion

This study aimed to investigate the impact of a concept mapping instructional strategy on the academic achievement of senior secondary Biology students in Ecology, with a specific focus on potential gender-based differences in its effectiveness. The research questions sought to determine (1) whether concept mapping leads to significantly higher achievement than the conventional lecture method, and (2) whether its effect differs between male and female students. Based on the analysis, the findings provide clear answers: students taught with concept mapping demonstrated significantly higher post-test scores than their counterparts taught with the traditional lecture method, and this positive effect was equivalent for both male and female students.

The significant superiority of the concept mapping group aligns with the core tenets of constructivist learning theory, which posits that knowledge is actively built by learners through the integration of new information with pre-existing cognitive structures (Novak, 1998). Concept mapping operationalizes this theory by providing a visual and hierarchical tool that requires students to identify key concepts, articulate relationships, and synthesize information into a coherent framework. This active process of organization likely promotes deeper cognitive processing, moving beyond rote memorization towards meaningful learning, which is essential for mastering the interconnected concepts in Ecology (Olagbaju & Oludipe, 2020). Our results strongly support and extend earlier findings on the efficacy of concept mapping in science education in Nigeria (Sakiyo & Waziri, 2015; Ibe & Kalu, 2022).

Furthermore, the finding of no significant gender difference in achievement within the concept mapping group is a crucial outcome. It suggests that, when implemented as described, concept mapping serves as a gender-inclusive pedagogical tool. This result supports contemporary research emphasizing equitable learning strategies that engage all learners effectively (Amosa et al., 2021). It may be that the structured yet flexible nature of concept mapping allows both male and female students to externalize and organize their understanding in a way that aligns with their individual cognitive processes, without privileging one group over another. This outcome, however, contrasts with some earlier studies that reported gender disparities with certain graphic organizers, highlighting that the specific design and implementation context of the instructional strategy are critical factors in mediating gender effects (Yusuf & Afolabi, 2020).

These findings have important implications for both educational theory and classroom practice. Theoretically, they reinforce the power of visual-kinesthetic and metacognitive tools within a constructivist framework for complex subject matter. Practically, the results provide empirical, localized evidence that can directly inform teacher training and curriculum development in Katsina State and similar contexts. Demonstrating that a single, well-structured strategy can simultaneously boost overall achievement and ensure equitable outcomes addresses two persistent challenges in Biology education. Therefore, integrating concept mapping into pedagogical repertoires represents a viable and impactful approach for improving science literacy and fostering inclusive learning environments in Nigerian secondary schools.

Conclusion

This study concludes that the concept mapping instructional strategy is significantly more effective than the traditional lecture method in enhancing the academic achievement of senior secondary students in Ecology. Furthermore, it is a gender-inclusive strategy that benefits the academic achievement of both male and female learners equally.

Recommendations

Based on these findings, it is recommended that:

i. Biology teacher training programs and continuous professional development workshops, such as those organized by the Science Teachers Association of Nigeria (STAN), should prioritize hands-on training in the development and application of concept mapping across various topics to enhance student academic performance.

ii. Curriculum planners and textbook authors should intentionally integrate concept mapping activities, examples, and templates into Biology instructional materials, particularly for complex and abstract topics like Ecology, to guide both teachers and students in improving academic outcomes.

iii. Secondary school administrators and educational quality assurance bodies should encourage and support teachers in adopting concept mapping as a regular instructional, revision, and assessment tool to promote deeper, more meaningful learning and improved academic achievement.

Suggestions for Further Research

Future studies could investigate the long-term retention effects of concept mapping on academic achievement, its efficacy in other Biology topics and STEM disciplines, its impact on the development of higher-order thinking skills, and its effectiveness in different educational contexts (e.g., junior secondary, tertiary education) across Nigeria.

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