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Effect of Main-Idea-Web Teaching Strategy on Achievement in Nutrient-Cycling in Nature and Pollution Concepts among Secondary School Biology Students in Kano State, Nigeria

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Abstract

This study investigated the effect of Main-Idea-Web (MIW) teaching strategy on secondary school students' academic achievement in Nutrient Cycling in Nature and Pollution in Kano State, Nigeria. The study adopted a quasi-experimental design involving pre-test, post-test, equivalent group. Population of the study consists of 11,290 SS11 students and a sample of 512 SSII students were taught using MIW strategy, while another group was taught using conventional teaching method. The instrument for data collection was a validated Nutrient Cycling in Nature and Pollution Achievement Test (NPAT). Data were analyzed using mean, standard deviation, and ANCOVA at 0.05 level of significance. Findings revealed that students taught with MIW strategy had higher mean achievement scores than those taught with the conventional method. ANCOVA results showed a significant difference between the two groups in favour of the experimental group ($F = 121.809, p < 0.05$). The study also found significant effects of gender and a significant interaction effect between instructional strategy and gender. The R^2 value indicated that a substantial proportion of variation in students' achievement was explained by the instructional strategy. The study concluded that Main Idea Web teaching strategy is more effective than conventional teaching method in improving students' academic achievement in Biology. It was recommended that Biology teachers should adopt MIW strategy to enhance students' understanding of complex biological concepts.

Keywords: Main-Idea-Web, achievement, Biology, Nutrient Cycling, Students

Introduction

Education is widely recognized as a fundamental instrument for national development, social transformation, and economic growth (FRN, 2014; UNESCO, 2015). Through education, individuals acquire the knowledge, skills, and values necessary for meaningful participation in society and sustainable development. In the same vein, science education plays a strategic role in fostering innovation, technological advancement, and global competitiveness (OECD, 2018). At the secondary school level, science subjects including Biology are designed to equip learners with scientific literacy and problem-solving skills. Among these subjects, Biology occupies a central position due to its relevance to health, agriculture, environmental sustainability, and biotechnology (Mohammad, Bala, & Bukar, 2021). Despite this importance, effective teaching remains crucial for achieving educational objectives and improving students' learning outcomes in Biology. Biology is the study of living organisms and their interactions with the environment (Hillis et al., 2020). It serves as a foundation for careers in medicine, nursing, agriculture, pharmacy, and other science-related fields (Salihu et al., 2022). Despite its relevance, students' achievement in Biology remains unsatisfactory, as many concepts are perceived as abstract and difficult (Othuke, 2019; Sadoh & Nwanegbo, 2023). Concepts such as nutrient cycling, pollution, genetics, respiration, and photosynthesis are frequently identified



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as challenging by secondary school students (Abidoeye, Abidoeye, & Olaide, 2023). Also, poor achievement in Biology has been attributed to factors such as inappropriate teaching methods, inadequate instructional materials, overcrowded classrooms, and students' negative attitudes toward the subject (Nwanegbo, 2022; Isah et al., 2022). Consequently, students often rely on rote memorization rather than meaningful learning, which negatively affects their academic achievement (Nooraida et al., 2020).

Academic achievement refers to the extent to which students attain instructional objectives and demonstrate mastery of concepts (Oyovwei, 2019). Therefore, improving achievement requires instructional strategies that promote meaningful understanding and active engagement. In response, researchers have advocated student-centered instructional strategies such as concept mapping, mind mapping, cooperative learning, and graphic organizers (Akanbi et al., 2021; Aina & Ogunkule, 2022). Graphic organizers are visual tools that help learners organize and relate concepts meaningfully, thereby enhancing comprehension of learned concepts (Christopher & Phillip, 2020). Among these strategies is the Main-Idea-Web technique, a form of graphic organizer that begins with a central concept and branches into related sub-concepts (Velarde, 2019; Kuthuria, (2019) Lynch, 2021). This strategy promotes active learning by helping students visually structure information, thereby improving understanding of complex concepts. Furthermore, this study focuses on Nutrient Cycling in Nature and Pollution, which are key topics in the Senior Secondary School Biology curriculum. These concepts are essential for understanding ecological balance, environmental sustainability, and climate-related issues (Ramalingam, 2018; UNEP-WCMC, 2023).

However, students continue to experience difficulties in understanding processes such as nutrient flow, environmental pollution, and diagrammatic representation and explanation of microbial roles such as Lightening, Nitrosomonas and Azotobacter (WAEC, 2019; Abidoeye et al., 2023). More so, persistent poor performance in Biology despite its compulsory nature highlights a gap between teaching methods and meaningful learning outcomes. In response, various innovative instructional strategies such as mind mapping, concept mapping, cooperative learning, and computer-assisted instruction have been proposed and put in place (Jafaru & Abbas, 2021; Bunkure & Shehu, 2021). However, empirical evidence on the effectiveness of Main-Idea-Web strategy in improving students' achievement in nutrient cycling and pollution remains limited. More importantly, gender was considered as a moderating variable in this study due to inconsistent findings in previous research regarding its effects on academic achievement (Syed et al., 2019; Usman & Idris, 2021). Some studies suggest differences in achievement between male and female students, while others report no significant difference. Therefore, this study investigates the effect of Main-Idea-Web teaching strategy on secondary school students' academic achievement in Nutrient Cycling and Pollution in Kano State, Nigeria, and examines whether gender influences students' achievement under this instructional strategy

Objectives of the Study

1. Find out the effect of main-idea-web teaching strategy on students' academic achievement in Nutrient Cycling in Nature and Pollution of senior secondary schools.
2. Find out gender difference among senior secondary school students' academic achievement in Nutrient Cycling in Nature and Pollution when taught with main-idea-web teaching strategy.

Research Questions

1. What is the mean difference in the academic achievements of students taught with main idea web, and those taught with conventional method?



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2. What is the mean difference in gender academic achievements of students taught nutrient cycling in nature and pollution with main idea web, and those taught with conventional teaching method?

Research Hypotheses

H₀₁: There is no significant mean difference in the academic achievement of students taught nutrients cycling in nature and pollution with main idea web, and those taught with conventional methods of teaching.

H₀₂: There is no significant mean difference in the academic achievement of male and female students taught nutrients cycling in nature and pollution with main idea web, and those taught with conventional methods of teaching

Research Methodology

The study adopted a quasi-experimental research design involving a pre-test and post-test non-equivalent control group. Quasi-experimental design was considered appropriate because it allows the researcher to determine cause-and-effect relationships between the independent and dependent variables through treatment and comparison of groups (Thomas, 2023). The population of the study comprised 11,290 SS2 students in all 28 public Senior Secondary Schools in Nassarawa Education Zone, Kano State, Nigeria. SS2 students were selected because Nutrient Cycling in Nature and Pollution are taught at this level. The students were assumed to be relatively homogeneous in age (15–17 years), exposed to the same curriculum, and learning under similar school environments. The sample consisted of 312 SS2 students drawn from four public secondary schools using intact classes. Intact classes were used because the classes were already organized and could not be randomly restructured. The research instrument used was the Nutrient Cycling in Nature and Pollution Achievement Test (NPAT), developed from WAEC SSCE past questions (2000–2025). The instrument consisted of 30 multiple-choice items with options A–D. Section A contained demographic information such as school, age, class, and gender, while Section B contained the test items. All items were structured to reflect Bloom’s taxonomy levels: knowledge, comprehension, application, analysis, synthesis, and evaluation. Each correct response was scored 1 mark, while incorrect responses were scored 0, giving a total maximum score of 30. The instrument was validated by experts in science education and measurement and evaluation. A split-half reliability of 0.75 was obtained using the Spearman’s rank-order correlation, indicating acceptable internal consistency for research purposes (Cohen, 1988; Dancy & Reidy, 2004). Data collected were analyzed using mean, standard deviation, and Analysis of Covariance (ANCOVA) at 0.05 level of significance.

Presentation of Results

Research Question One: What is the mean difference in the academic achievements of students taught with main idea web and sequence chart and those trained with the conventional method?

Table 1: Mean Difference of the Effect of Main Idea Web on SSII Academic Achievement

Variables	Group	N	\bar{x}	SD	M/dff	Remark
Main Idea Wave	Experimental	98	21.03	2.27		Main Idea Web Affect Students Achievement
	Control	85	16.41	3.31	4.62	

Table 1 present a mean difference between the experimental and control group of main idea web and conventional teaching method. From the Table, the academic achievement of the students taught with Mai-idea-web were closed to each other ($\bar{x} = 21.03$, $SD = 2.27$) as the standard deviation indicated less dispersed, meaning that the standard deviation is quite smaller than the mean. The same thing in the control group ($\bar{x} = 16.41$, $SD = 3.31$). The mean difference between the experimental



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and control group is 4.62 in favour of the experimental group, thus Main-idea-web has effect on the students' academic achievement.

H₀₁: There is no significant mean difference in the academic achievement of students taught nutrients cycling in nature and pollution with main idea web teaching strategies, and those taught with conventional methods of teaching.

Table 2 ANCOVA Result Academic Achievement for Main Idea Web (MIW)

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	971.139 ^a	2	485.570	61.402	.000
Intercept	3801.338	1	3801.338	480.692	.000
MIW_Pre_test	.045	1	.045	.006	.940
Group	963.277	1	963.277	121.809	.000
Error	1423.451	180	7.908		
Total	67662.000	183			
Corrected Total	2394.590	182			

a. R Squared = .406 (Adjusted R Squared = .399)

Dependent Variable: MIW_Post_test

Table 2 revealed the results of an Analysis of Covariance (ANCOVA) conducted to examine the effect of Main-Idea-Web on students' academic achievement (Posttest), while controlling for pretest achievement (MIW_Pre_test). The corrected model was statistically significant.

$F(2,180) = 61.40, p < 0.001$, indicating that the combined effects of the covariate and group significantly explained variance in students' MIW posttest scores. The model accounted for 40.6% of the variance in the dependent variable ($R^2 = .406$; Adjusted $R^2 = .399$), suggesting a moderate to high explanatory power. The covariate, MIW_Pre test, did not have a statistically significant effect on posttest scores, $F(1,180) = 0.01, p = 0.940$. This result indicates that students' pretests did not significantly influence their posttest outcomes after controlling for group differences. However, the group effect was statistically significant, $F(1,180) = 121.81, p < 0.001$. This finding demonstrates that there was a significant difference in MIW posttest scores between the experimental and control groups after adjusting for pretest scores. Thus, the Mai-Idea-Web instructional strategy had a strong and meaningful effect on students' academic achievement (posttest). The intercept was also statistically significant $F(1,180) = 480.69, p < 0.001$, indicating that the adjusted mean posttest score differed significantly from zero when all predictors were held constant. In summary, the ANCOVA results show that while pretest performance did not significantly predict MIW posttest scores, instructional group exerted a strong and statistically significant effect on students' posttest outcomes. This suggests that the Main Idea Web instructional strategy was effective in improving students' achievement compared to the control group.

Research Question Two: What is the mean difference in gender academic achievements of students taught nutrient cycling in nature and pollution with main idea web, and those taught with conventional teaching method?

Table 3: Mean Difference between Male and Female Students' Academic Achievement

Gender	Group	N	\bar{x}	SD	M/diff	Remark
Male MIW	experimental	39	19.72	1.28	5.84	
	Control	34	13.88	2.25		
Female MIW	Experimental	59	21.90	2.38	3.80	
	Control	51	18.10	2.80		



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Table 3 presents the mean difference of male and female students' academic achievement scores between experimental and control groups exposed to the Main-Idea-Web (MIW) and Conventional teaching method. For Main-Idea-Web, male students in the experimental group had a mean score of 19.72 ($SD = 1.28$), which was higher than that of the control group, with a mean score of 13.88 ($SD = 2.25$). The mean difference of 5.84 indicates that the Main-Idea-Web strategy significantly improved academic achievement among male students. Likewise, female students in the experimental group exposed to the Main-Idea-Web obtained a higher mean score ($M = 21.90$, $SD = 2.38$) than their control counterparts, who recorded a mean score of 18.10 ($SD = 2.80$). The mean difference of 3.80 shows that the Main-Idea-Web strategy also enhanced academic achievement among female students. By implication, the findings indicate that Main-Idea-Web strategies was effective in improving students' academic achievement across gender. However, the magnitude of improvement was consistently higher among male students than female students for Main Idea Web strategies. This suggests a possible interaction between gender and instructional strategy on students' academic achievement, with male students benefiting more strongly from the interventions.

HO₅: There is no significant mean difference in the academic achievement of male and female students taught nutrients cycling in nature and pollution with main idea web teaching strategy, and those taught with conventional methods of teaching.

Table 4: ANCOVA for Male and Female academic achievement exposed to MIW

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1447.418 ^a	4	361.854	68.002	.000
Intercept	3223.641	1	3223.641	605.812	.000
MIW_Pre_test	2.154	1	2.154	.405	.525
Group	1015.682	1	1015.682	190.875	.000
Gender	447.469	1	447.469	84.092	.000
Group * Gender	38.150	1	38.150	7.169	.008
Error	947.172	178	5.321		
Total	67662.000	183			
Corrected Total	2394.590	182			

a. R Squared = .604 (Adjusted R Squared = .596); Dependent Variable: MIW_Post_test

A two-way ANCOVA was conducted to examine the effects of group and gender on MIW post-test scores while controlling for MIW pre-test scores. The overall model was significant, $F(4,178) = 68.002, p < 0.001$, explaining 60.4% of the variance in post-test scores. The covariate (MIW pre-test) was not significant, $F(1,178) = 0.405, p = 0.525$. There was a significant main effect of group, $F(1,178) = 190.875, p < 0.001$, and gender, $F(1,178) = 84.092, p < 0.001$. Additionally, the interaction between group and gender was significant, $F(1,178) = 7.169, p = 0.008$, indicating that the effect of group on MIW post-test scores varied by gender.

Discussion of Findings

The findings of Research Question One revealed that students taught Nutrient Cycling in Nature and Pollution using the Main Idea Web (MIW) teaching strategy had higher academic achievement than those taught using the conventional The ANCOVA result further confirmed that this difference was statistically significant ($F = 121.809, p < .05$), leading to the rejection of the null hypothesis. This finding is consistent with recent empirical studies on visual and graphic organizer-based



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instructional strategies. For example, Ugwoke and Ude (2022); Hasanah and Adlini (2023) reported that students taught Biology using mind mapping strategies significantly outperformed those taught with conventional methods in secondary schools. In addition, Onah, Anamezie, and Nnadi (2022) also reported that mind map graphic organizers significantly improved students' academic performance in physics, supporting the effectiveness of structured visual learning tools. However, Gaven et al., (2022) found that although students' performance improved during learning activities, mind mapping did not produce significantly higher achievement. Also, Laleye (2022) reported that although graphic advance organizers improved students' achievement in basic science the level of improvement was not significantly higher under all instructional conditions.

The findings of table four and five revealed that male and female students taught Nutrient Cycling in Nature and Pollution using the Main Idea Web (MIW) teaching strategy performed significantly better than those taught using the conventional method. The ANCOVA result indicated a significant difference in favour of the experimental group ($F = 190.875, p < .05$). The study also revealed a significant effect of gender on academic achievement, with female students slightly outperforming male students. This finding aligns with study of Ugwoke and Ude (2022) who found that female students outperformed the male counterpart when taught with instructional strategies. Anaekwe and Nnaka (2020) reported that female students performed better under collaborative learning strategies in Biology. However, the study contradicts the studies of Opara and Ayanarillaye (2020); Birabel and Brown (2020); Oyibo (2020) who found significant difference of instructional strategies on male and female students, with the male student performing higher than the female students. The present finding therefore suggest that while MIW is effective for both male and female students, the degree of effectiveness may vary slightly across gender.

Conclusion

The study concluded that Main Idea Web teaching strategy is more effective than conventional teaching method in improving students' academic achievement in nutrient cycling in nature and pollution. It also enhances meaningful learning and cognitive organization of Biological concepts.

Recommendations

Based on the findings, the following were recommended:

1. Biology teachers should adopt Main Idea Web strategy in teaching complex concepts.
2. Curriculum planners should integrate graphic organizers such as main-idea-web into Biology curriculum.
3. Teachers should be trained on the use of MIW and other visual learning strategies.

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