

**CRITICAL THINKING DISPOSITION AND BIOLOGY STUDENTS' ACHIEVEMENT:
COMPARATIVE EFFECTS OF THE 4MAT AND 5E INSTRUCTIONAL
APPROACHES**

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Abstract

This study examined the comparative effects of 4MAT and 5E instructional approaches on the academic achievement and critical thinking disposition of biology students in Imo State, Nigeria. For this study, a quasi-experimental design was used. The sample comprised 85 SS2 Biology students, selected using purposive sampling technique. Using two validated instruments named Biology Achievement Test (BAT) and Biology Critical Thinking Disposition Rating Scale (BCTDRS), data on student achievement and critical thinking disposition were collected. To test the instruments for reliability, Kuder Richardson 20 was used for the BAT and Cronbach Alpha statistics for the BCTDRS and coefficients of 0.77 and 0.75 were obtained respectively. To answer the questions posed, the researcher utilized mean and standard deviation scores, while the hypotheses were tested with ANCOVA F-test at 0.05 significance. The findings of the study are as follows: students taught Biology by employing the 5E instructional approach significantly outperformed those taught using the 4MAT method ($p < .05$), while those taught using the 4MAT method significantly performed better in their critical thinking disposition than their counterparts taught using the 5E ($p < .05$). The researcher recommended that biology teachers adopt the 5E method for improved academic achievement and 4MAT for improved critical thinking disposition.

Keywords: 4MAT, 5E, Academic achievement, critical thinking disposition

Introduction

The field of Science Education concerns itself with instructing individuals about their world through observation and experimentation. The indispensable nature of science and technology in this dispensation cannot be overemphasized, and as such, countries strive to remain forward in technological and scientific advancements. Science education encompasses various subjects, including Biology, Chemistry, Physics, and sometimes agricultural science.

Biology is an important branch of science taught in senior secondary schools in Nigeria. Biology is generally known as the study encompassing life. It is also concerned with the different relationships that exist between organisms and their environments. Biology is a prerequisite subject in major scientific fields and extends to some aspects of the social sciences. Given the crucial role of biology, significant attention has been directed towards teaching it, particularly in secondary schools. This is to guarantee the complete achievement of the goals outlined in the

biology curriculum, as specified by the National Policy on Education. (FRN, 2013), which includes preparing students for the acquisition of proper laboratory skills, meaningful biological knowledge, purposeful scientific attitudes and methods, and ways to apply scientific knowledge to daily life.

Over time, various science educators have voiced the necessity to maintain good standards of achievement and interest in biology. These good standards and outcomes in biology have been hampered over the years by the teaching approaches used to deliver biology instruction (Ezere & Ndirika 2022). Students are constantly exposed to rote learning and examination misconduct because of their inability to actively engage in the learning process. This is mostly due to the nature or mode used to deliver the biology instruction. To proffer methods that reduce rote learning and enhance the active participation of students, Ezere and Ndirika (2022) proposed that conventional teaching approaches be augmented or, in some cases, substituted with innovative teaching approaches. Some of these innovative approaches are believed to be learner-centered and help enhance students' understanding of scientific concepts. It is also important that instructional approaches that cater to the individual needs of every learner be incorporated into biology classrooms to promote high levels of academic achievement.

The extent to which students perform in any given subject is influenced by their inherent learning style. For instance, some learners are more productive when learning science through practical activities (experiments), whereas others may perform better by studying the processes involved in the lesson and internalizing them. In addition, some learners prefer to study individually, while others thrive in group-learning settings (Alanazi, 2020). The individual differences of various students have not been factored in by many of the teaching methods used by biology teachers to deliver instruction, which may be a strong explanation for the observed poor achievement and low critical thinking abilities among biology students. Research has shown that students comprehend and perform better when different learning methods are represented in the instructional approach used by teachers (Ndirika, 2012).

Consequently, an instructional approach or model that caters to the various learning styles of students is the four-mode application technique, which is widely known as the 4MAT instructional approach/method. According to Alanazi (2020), the four-mode application technique

(4MAT) instructional approach is a strategy that mainly focuses on the learner with regard to each learner's peculiar need. Bernice McCarthy developed this instructional approach in 1970. This approach converts concepts or philosophies pertaining to learning styles into instructional plans and strategies. This approach contains eight steps/cycles that consider the four different primary learning preferences and brain dominance patterns of individuals.

The four primary learning styles/preferences popularized by Bernice McCarthy in 1970 include imaginative, analytical, common sense, and dynamic learners. In the use of the 4MAT instructional approach, the four basic learning styles are always embodied in a circle divided into four quadrants, where each quadrant has two steps (representing individuals with one learning preference), and this sums up the 8-step strategy for teaching and learning using the 4MAT approach. Based on McCarthy's proposition, there are two major tenets of the 4MAT model: first, every individual has a preferred learning mode and hemispheric method of processing information (right and left modes); second, teachers are expected to build and use a vast array of instructional steps within a methodical outline to teach learners who have or share similar preferences for an enhanced learning experience. The 4MAT model offers an outline that students can use to adapt to the teachings and philosophies expected of high school students while helping learners become more aware of their learning strengths and weaknesses (Ibenegbu & Nzewi, 2020). Murtala et al. (2022) explored how the 4MAT Instructional Model influences the interest and performance of upper basic 3 students in Algebra. Their study revealed that employing the 4MAT instructional model enhanced both students' achievement and interest in algebra more than the traditional instruction approach. Similarly, Bataineh, Hailat, Khasawneh, and Jawarneh (2020) examined the direct and delayed academic outcomes of students in social studies when taught using the 4MAT strategy. Their findings revealed notable distinctions between the outcomes of the students exposed to 4MAT and the control group in terms of both immediate and delayed academic performance, favoring the former. This suggests that the 4-MAT teaching method was effective in enhancing the academic success and long-term retention of social studies concepts among secondary students in Jordan. Alanazi (2020) investigated the impact of the 4MAT teaching method on seventh-grade female students' understanding of electricity usage. The research revealed significant statistical differences in the students' grasp of electricity concepts in physics between the 4MAT and control groups, with the 4MAT group showing higher performance. These

studies have been carried out to show the efficacy of the 4MAT teaching method; however, gaps remain in the use of this method in the teaching of biology, specifically among senior secondary school students in Imo State.

Another approach to teaching science that considers students' learning styles and strengths is the 5E instructional method. This instructional approach is based on constructivist learning approaches. The rudimentary goal of this model is to aid students in developing novel notions and ideas in addition to their existing ideas and to apply them for enriched learning experiences (Kibici, 2022). The 5E instructional approach, also known as the 5E Model, was formulated by the Biological Sciences Curriculum Study (BSCS) in 1987 as a modification of the Atkin-Karplus learning cycle of the 1960s (Gu, 2023). The 5E is an abbreviation for a sequence of five phases for planning classroom lessons: These five phases are: engagement, exploration, explanation, elaboration, and evaluation. These five phases, as briefly explained by Cardak, Dikmenli, and Saritas (2008), are as follows: Engagement: In this phase, activities are planned to attract students' attention and arouse interest in a bid to help them gain access to their previous knowledge. In the Exploration phase, students are allotted time to process, plan, think, examine, and arrange the compiled information. In the explanation phase, students analyze their explorations through the use of reflective endeavors and activities to which they were exposed in the previous stage. The elaboration phase involves encouraging students to expand and concretize their understanding of the concepts to which they are being exposed and to apply these concepts in real-world settings. The last phase, which is the evaluation phase, occurs throughout the lesson; that is, the teacher monitors students' knowledge and skills in line with how they apply these new concepts and how their change in thinking is reflected.

Suwito, Budijanto, Handoyo, and Susilo (2020) argued that the 5E instructional approach is effective in ensuring higher academic outcomes at both cognitive and affective levels. They further noted that this approach (5E) holds great promise for improving the critical thinking abilities of secondary school students. This is the result of a study conducted among students that reported improved achievement levels among students who were exposed to the 5E instructional method. Okafor (2017) carried out research to assess the impact of the 5E-Learning Cycle Model (L.C.M.) on the performance and retention of SS1 students in geometry in Anambra State. The findings of

this study indicated that 5E L.C.M. significantly influenced students' achievement and retention in geometry. Similarly, Omotayo and Adeleke (2017) implemented a quasi-experimental research design to investigate the differences between the achievements and interests of students taught mathematics using the 5E learning cycle and lecture method in Ibadan Metropolis. Following the implementation of the 5E instructional model, a significant post-test effect of treatment was observed on students' mathematics achievement. This indicates a notable impact of treatment on students' performance in mathematics. Furthermore, Suwito, et al (2020) conducted research on how the 5E learning cycle model impacts students' academic performance in the field of population geography. Their results showed that the group that learned using 5E had significantly improved outcomes. These studies have shown that the 5E teaching method is effective in improving geometry, mathematics, and geography. Gaps also exist in the effectiveness of the model for improving achievement in subject biology and for improving critical thinking disposition.

Critical thinking is the act of carefully analyzing, breaking down, and examining phenomena to provide the best solutions and make proper decisions. Paul and Elder (2019) described critical thinking as a component of thought that pertains to any topic or content. It involves a thorough analysis, assessment, and restructuring of one's thinking to enhance quality of their thoughts. According to Ilkorucu, Broutin and Boyaci (2022), a good critical thinker is one who is able to pose open questions and sequentially complete the process of arriving at answers to these questions by collecting and evaluating pertinent information to explain abstract or complex ideas. To achieve success in the sciences, there is a high expectation placed on students to think critically and develop strong skills for problem-solving. Various studies have been conducted on the individual effects of 4MAT and 5E on student achievement and critical thinking disposition. However, there is a dearth of knowledge specifically comparing the effects of these two approaches on the achievement and critical thinking disposition of biology students. This constitutes a gap that this study seeks to fill.

Purpose of the study

The following two purposes guided this study and specifically, the study determined:

1. the mean achievement scores of students taught biology using the 4MAT and 5E instructional approaches.
2. the mean critical thinking disposition scores of students taught biology using the 4MAT and 5E instructional approaches.

Research questions

Two research questions guided this study.

1. What are the mean achievement scores of students taught biology using the 4MAT and 5E instructional approaches?
2. What are the mean critical thinking disposition scores of students taught biology using the 4MAT and 5E instructional approaches?

Hypotheses

HO1: The mean achievement scores of students taught Biology using 4MAT and 5E instructional approaches do not differ significantly

HO2: There is no significant difference between the mean critical thinking disposition scores of students taught biology using the 4MAT and 5E instructional approaches.

Methods

The researcher adopted a quasi-experimental research design (two intact groups with pre-test, treatment, and post-test procedures). The sample comprised 85 SS2 Biology students. A purposive sampling technique was used. Two Local Government areas in Owerri Education Zone I of Imo State were randomly selected for the study. One coeducational school in each of the selected local government areas was purposively selected for the study, from which SS2 class was purposively picked from each of the schools. The researcher randomly assigned the schools to experimental group I (4MAT), consisting of 37 students, and to group II (5E), consisting of 48 students. Group I was taught excretion, nutrient cycling in nature, and ecological management (Associations, Adaptation and Pollution) using the 4MAT approach, while Group II was taught

the same topics using the 5E model. The instruments used for data collection were the Biology Achievement Test (BAT) created by the researcher and the Biology Critical Thinking Disposition Rating Scale (BCTDRS) modified from Irani et al. (2007). The BAT consists of 50 multiple-choice questions scored dichotomously. The BCTDRS is a 16 item rating scale answered in a 4-point likert format of Strongly agree (4points), Agree (3 points), Disagree (2 points), and Strongly disagree (1 point). Five specialists validated the instruments. To test for reliability of the instruments, Kuder Richardson 20 was used for the BAT and Cronbach Alpha statistics for the BCTDRS and coefficients of 0.77 and 0.75 were obtained respectively. A pre-test was administered to the SS2 students in the two schools using the BAT and BCTDRS, which served as covariates for the statistical analysis. The students were given the BAT and BCTDRS (the instruments were reshuffled) as post-tests after treatment. To control for extraneous variables, biology teachers in the participating schools handled the teaching. The participating SS2 Biology teachers were trained by the researcher using a guide for the 4MAT and 5E approaches, and the students were not notified of their participation in the research prior to treatment. Additionally, ANCOVA was used in the analysis to partially account for initial group differences. To address the research questions, the mean and standard deviation were utilized, and ANCOVA was employed to test the hypotheses. F-test at 0.05 significance level, where p-value of <.05, led to rejection of the null hypothesis and vice versa.

Results

RQ1: What are the mean achievement scores of students taught biology using the 4MAT and 5E instructional approaches?

Table 1: Average achievement scores of students who learned Biology through the 4MAT and 5E instructional approaches

Test: Academic achievement		Pre-test		Post-test	
Instructional approaches	N	$\bar{x}$	S	$\bar{x}$	S
4MAT approach	37	18.00	3.38	30.29	6.95
5E approach	48	17.77	2.01	37.41	6.98

Table 1 shows the mean achievement scores of students taught biology using the 4MAT and 5E instructional approaches. The data show that students taught using the 5E method

outperformed their counterparts (mean= 37.41) taught using the 4MAT approach (mean=30.29) in the post-test. The standard deviation scores were low compared to the mean, implying homogeneity of the scores.

HO₁: The mean achievement scores of students taught Biology using 4MAT and 5E instructional approaches do not differ significantly

Table 2: ANCOVA F-test Analysis for the test of significant difference between achievement scores of biology students taught using 4MAT and 5E instructional approaches

Tests of Between-Subjects Effects					
Dependent Variable: Achievement Post-Test Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	4004.981 ^a	2	1334.994	35.025	.000
Intercept	3611.701	1	3611.701	94.756	.000
Pre_test	8.161	1	8.161	.214	.644
Group	4002.884	2	2001.442	52.510	.000
Error	4612.011	82	38.116		
Total	128680.000	85			
Corrected Total	8616.992	84			

a. R Squared = .465 (Adjusted R Squared = .542)

Table 2 presents the results of the ANCOVA test examining the significant difference in the average achievement scores of students who were taught biology using the 4MAT and 5E instructional approaches. The calculated F-value is 52.510, with an associated p-value of 0.000. Given that the p-value is below 0.05, the null hypothesis is rejected, leading to the conclusion that there is a significant difference in the mean achievement scores of students taught biology using the 4MAT and 5E approaches.

RQ2: What are the mean critical thinking disposition scores of students taught biology using the 4MAT and 5E instructional approaches?

Table 3: Mean critical thinking disposition scores of students taught Biology using 4MAT and 5E instructional approaches

Test:	Critical thinking disposition		Pre-test		Post-test
		N	$\bar{x}$	S	$\bar{x}$ S
Instructional approach					
4MAT approach		37	40.05	8.27	56.18 7.16
5E approach		48	39.47	8.73	51.31 5.75

Table 3 presents the mean critical thinking disposition scores of the students taught using the two instructional approaches. The data show that in the post-test, the students taught biology using the 4MAT had higher critical thinking disposition scores (56.18) than their counterparts taught using the 5E method (51.31).

HO₂: There is no significant difference between the mean critical thinking disposition scores of students taught biology using 4MAT and 5E instructional approaches.

Table 4: ANCOVA F-test Analysis for the Test of significant difference among the mean critical thinking disposition scores of students taught Biology with 4MAT and 5E instructional approaches

Tests of Between-Subjects Effects					
Dependent Variable: Critical thinking disposition Post-Test					
Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	839.837 ^a	2	279.946	7.156	.000
Intercept	12592.144	1	12592.144	321.892	.000
Pre_test	112.552	1	112.552	2.877	.092
Group	712.722	2	357.361	9.135	.000
Error	4733.411	81	39.119		
Total	350157.000	85			
Corrected Total	5573.248	84			

a. R Squared = .151 (Adjusted R Squared = .130)

The results in Table 4 show an F-calculated value of 9.135 with an associated p-value of 0.000, which is less than 0.05. This led to the rejection of the null hypothesis, implying a significant difference between the mean critical thinking disposition scores of students taught biology using 4MAT and 5E instructional approaches.



Discussion

Findings from the first research question and corresponding hypothesis (Tables 1 and 2, respectively) show that students who learned biology through the 5E instructional approach significantly outperformed those who were taught using the 4MAT approach. The 5E instructional method may have produced higher academic achievement, given that although the approach is being used in different educational fields, the proponents of this instructional approach proposed that it would be very effective in the teaching of sciences. In addition, the 5E approach focuses on a deep understanding of scientific concepts and processes with five phases aligned with the scientific inquiry process: engaging (activating prior knowledge, sparking curiosity), exploring (gathering data, making observations, asking questions), explaining (developing explanations, constructing models, connecting ideas), elaborating (applying understanding to new situations, solving problems), and evaluating (assessing learning, revising understanding, communicating findings). This finding aligns with the research conducted by Yakubu and Amwe (2019), who investigated the impact of the 5E instructional model on students' achievement in Basic Science and Technology. Their study revealed a significant difference in the performance scores of participants taught using the 5E model compared to those instructed through traditional teaching methods, with the 5E group demonstrating superior performance. Suwito et al (2020) also corroborates the findings above in their study on effect of the 5E learning cycle model on students' learning achievement in population geography where they recorded significant differences in the achievement of students taught with 5E and lecture method. They further concluded that the 5E model was the best choice of instructional method to improve achievement.

The findings from the second research question and corresponding hypothesis (Tables 3 and 4) show that the 4MAT instructional approach significantly improved the critical thinking disposition of students in Biology more than the 5E instructional approach. This finding aligns with the research conducted by Ilkorucu, Broutin, and Boyaci (2022), who investigated the impact of integrating critical thinking based on 4MAT (CT-4MAT) instruction on students' critical thinking disposition. Their study recorded a significant enhancement in the critical thinking disposition of students exposed to 4MAT instructions. However, the findings above are debunked

by Siwawetkul and Koraneekij (2020), who, in a similar study, recorded that the 5E instructional model was best in increasing students' critical thinking and reasoning abilities.

Conclusion

The study has shown that while the 4MAT instructional approach was found to be more effective in improving the critical thinking disposition of the students in Biology, the 5E model produced students with higher academic achievement. This suggests that biology teachers and other educators stand to benefit significantly by incorporating both approaches in their classroom teaching. Furthermore, the incorporation of both the 4MAT and 5E instructional approaches would serve as a positive and planned response to the various learning styles present in any classroom setting. This will help teachers effectively cater to the personal needs of every learner.

Limitations of the findings

The validity of the study's findings is limited by the use of self-answered rating scale for the critical thinking disposition scale, which may have been prone to biased answers. In addition, absenteeism of some students may have made it difficult for them to follow up on lessons after missing any class, which may have affected the findings.

Recommendations

The researcher made the following recommendations:

1. Biology teachers should adopt the 4MAT and 5E teaching methods in teaching the subject Biology. However, the 5E model should be specifically adopted to improve academic achievement in biology.
2. The 4MAT teaching method should be adopted by Biology teachers especially for the improvement of students' critical thinking disposition.

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