EFFECTS OF 5E-CYCLIC AND MENTAL MODELS ON CONCEPTUAL SUCCESS OF STUDENTS IN ENERGY CONCEPTS IN BASIC SCIENCE IN ONDO STATE, NIGERIA

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Abstract
The study investigated the effects of 5e-cyclic and mental models on conceptual success of students' in energy concepts in Basic Science. The study employed 3x2 factorial matrix of non-equivalent, pre-test, post-test control group quasi-experimental research design. The population for the study comprised all junior secondary school students in Ondo State. The sample size consisted of 95 junior secondary school two (JSII) students in three intact classes. Two instruments were used for data collection namely: Basic Science Concept Test (BSCT) and Basic Science Anxiety Rating Scale (BSARS). Data collected were analysed using analysis of covariance (ANCOVA). The results showed that there was significant effect of 5e-cyclic and mental models instructional strategies on junior

secondary school students' academic performance in Basic Science ($F(_{2, 91}) = 27.403$; $P < 0.05$; partial $\eta^2 = .376$). The result also revealed that there was no significant effect of the strategies on students' anxiety towards Basic Science ($F(_{2, 91}) = 1.409$; $P > 0.05$; partial $\eta^2 = .030$). Furthermore, the result showed that there was no significant interaction between treatment and gender on students' academic performance in Basic Science ($F(_{2, 88}) = .888$, $P > 0.05$, partial $\eta^2 = .020$); between the treatment and gender on students anxiety towards Basic Science ($F(_{2, 88}) = 1.067$, $P > 0.05$, partial $\eta^2 = .024$).The study concluded that 5e-cyclic and mental models improved the students' academic performance in Basic Science. Therefore, it was recommended that teachers should use 5e-cylic model and mental model instructional strategies to improve student's success in basic science concepts.

Keywords: 5e-cyclic, Mental Model, Expository Method, Academic Performance, Self-efficacy

Introduction

Despite increased knowledge of science's role in a nation's socioeconomic and technological growth, declining student enthusiasm and performance in science concepts has been a source of concern in Nigerian classrooms. A matter of energy manifests itself in almost every area of our lives such as an incident, event or our experiences with a mechanical device or technological device that is not enough to explain energy. In the lower grades of secondary schools, science disciplines are primarily descriptive (Caspi, et. al, 2019). Exciting demonstrations are frequently used to keep students engaged without teaching them anything. Science's true character as a puzzle to be solved is not made evident. Many students grow apprehensive when they are confronted with the realities of science.

Furthermore, children's early scientific skills establish the groundwork for understanding scientific concepts later on. Students' understanding, conceptualization and application of scientific ideas are aided by these abilities. Students' enthusiasm and confidence in new options for science study are greatly influenced by successful early experiences in science. Many students who are falling behind

their peers in mastering essential foundational abilities in science may benefit from carefully planned individual or small group instruction combined with additional practice, explanation, and feedback (Lang, 2021). As a result, students will benefit from customizing scientific instruction in the early years. Individual factors of students like gender, interest in science, self-concept, self-efficacy, developmental preparedness, attitude, anxiety, poor focus, memory, coordination, and motivation, as well as punishment and verbal criticism, hinder students' performance in Basic Science (Ogbo, 2017).

Equally, the Basic Science curriculum emphasizes a paradigm shift from behaviorism to constructivism in order to improve conceptual learning in science and the development of interest in science and technology (Ahmad, Sultana & Jamil, 2020). This curriculum necessitates teaching-learning practices that engage students in their own knowledge production, putting them at the center of the learning process and the instructor as a facilitator. Nevertheless, the expository instruction of teaching science subjects like Basic Science has been criticized as being too teacher-centred; incapable of enhancing conceptual changes and conceptual understanding of emerging concepts in Basic Science. Two instructional models that have been adjudged to enhance students learning outcomes in Mathematics, Chemistry, and Biology are 5E-cyclic and mental models.

5E-Cyclic model as a pedagogical approach is based on constructivism where learners construct their own knowledge (Sharma, 2018). The curriculum of science education at the school level demands that highly successful 5E learning cycle model should be expanded in learning science. Such a change in the 5E model is not suggested to add complexity but to ensure the facilitators do not to omit crucial components for learning. According to Amini and Usmeldi (2019), 5E-cyclic model requires students to be able to convey ideas to solutions to problems. The model leads students through five phases of learning begin with the letter E: Engagement, Exploration, Explanation, Elaboration and Evaluation.Mental models are an intrinsic representation in the form of objects, ideas, or

processes that arise during the cognitive process to give reasons, describe, explain, or predict a phenomenon (Wang, 2007).

In basic science learning, students' mental models can be known from the way of students represent the three levels of energy representation and their interconnection. Each student has a different perspective and understanding of energy concepts so that the mental models of each student is different (Laliyo, 2011). This difference can be influenced by several factors, such as teacher instruction, textbooks, language and sentences, social environment, and students' intuition (Lin & Chiu, 2010). Mental models into three types, namely scientific, synthetic, and initial mental models (Kurnaz & Eksi, 2015). Scientific mental models can be built if students have the ability to develop critical thinking skills and are supported by good scientific learning. In reality, students are less able to develop critical thinking skills and solve problems so that students have difficulty in building scientific mental models. Some studies of mental models find that many students have very simple mental models of chemical phenomena, for example, atomic and molecular models are described as discrete and concrete structures, but students do not have the skills to build more complex mental models (Chittleborough & Treagust, 2007). The extent to which these models could enhance students learning outcomes in Basic Science based on gender incite investigation, hence this study.

Statement of the Research Problem

The expository approach has been criticized for its inability to improve conceptual comprehension of a new idea in basic science. The 5E-cyclic and mental models had proved effective in enhancing students learning outcomes in some science concepts. However, studies on effects of 5E-cyclic and mental models on students' conceptual understanding of energy concepts in Basic Science are still scanty particularly in the study area. The effects of these models on students' knowledge and anxiety towards energy concepts in Basic Science, based on gender, incites investigation; hence this study.

Objectives of the Study

i. investigate the effects of 5e-cyclic and mental models

instructional strategies on students' conceptual understanding of energy concepts in Basic Science;

ii. assess the effects of 5e-cyclic and mental models instructional strategies on students' anxiety towards energy concepts in Basic Science;

iii. examine the interaction effects of the two instructional strategies and gender on students' conceptual understanding of energy concepts in Basic Science; and

iv. assess the interaction effects of the two instructional strategies and gender on students' anxiety towards energy concepts in Basic Science.

Hypotheses

The following hypotheses were formulated to guide the study;

H_o1: There is no significant main effect of 5E-cyclic and mental models instructional strategies on students' conceptual understanding of energy concepts in Basic Science.

H_o2: There is no significant main effect of 5E-cyclic and mental models instructional strategies on students' anxiety towards energy concepts in Basic Science.

H_o3: There is no significant interaction effect of the two instructional strategies and gender on students' conceptual understanding of energy concepts in Basic Science.

H_o4: There is no significant interaction effect of the two instructional strategies and gender on students' anxiety towards energy concepts in Basic Science.

Methodology

The study employed 3x2 factorial matrix of non-equivalent, pre-test, post-test control group quasi-experimental research design. The population of the study comprised all junior secondary school students in Ondo State. The sample size consisted 95 Junior Secondary Two (JSII) students in their intact classes. Multistage sampling procedure was employed in selecting the sample for this study. Out of the three senatorial districts in the state, one senatorial district was selected using simple random sampling technique. Three Local Government Areas (LGAs) were selected from the senatorial

district and one school was selected from each of the LGA using simple random sampling technique. From each of the selected school, one intact class of JSII students was selected using simple random sampling technique and they were randomly assigned to two experimental groups and one control group. Experimental groups A and B were taught using 5E-cyclic-model and Mental-model instructional strategies respectively, while the control group was taught using teacher expository method. Two instruments were used for data collection namely: Basic Science Concept Test (BSCT), and Basic Science Anxiety Rating Scale (BSARS). The BSCT was used as pre-test and post-test to measure the students' conceptual understanding of energy concepts in Basic Science while BSARS was used to examine the students' anxiety before and after the intervention. The design is represented schematically as follows:

O_1	X_1	O_2	- Experimental Group A
O_3	X_2	O_4	- Experimental Group B
O_5	C_1	O_6	- Control Group C

where O_1 ; O_3 and O_5 are the pre-test scores of the experimental groups A; B and control group C; while O_2 ,O_4 and O_6 are their respective post-test scores for experimental groups A; B and control group C.

X_1= 5E-cyclic-model Instructional Strategy (5EIS)

X_2= Mental-model Instructional Strategy (MIS)

C_1=Expository Method (EM)

Validation of the Instruments

The validity of the drafted Basic Science Concepts Test (BSCT) and Basic Science Anxiety Rating Scale (BSARS) were submitted to experienced Basic Science teachers in junior secondary schools, and experts in test development for face and content validity. They were requested to check for the appropriateness of the items and content coverage considering the grade level of the students and the objectives of the study. Based on their comments and suggestion, which included revising some of the items and dropping some. Thereafter, the two instruments were administer on some selected students outside the scope of study but have similar characteristics as selected students used for the study. The reliability co-efficient of BSCT was determined by using Kuder-Richardson Formula 20while

that of BSARS was determined using Cronbach Alpha reliability index. The reliability coefficient for the BSCT was found to be 0.90and the reliability index for BSARS was calculated to be 0.94. The quantitative data collectedwere analyzed using analysis of covariance (ANCOVA).

Results

Hypothesis One (Ho_1):There is no significant main effect of 5E-cyclic and mental models instructional strategies on students' conceptual understanding of energy concepts in Basic Science.

Table 1
Analysis of Covariance Effect of 5ECMIS and MMIS on Students' Conceptual Understanding of Energy Concepts in Basic Science

Source	Type III Sum of Square	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	12580.770[a]	3	4193.590	34.598	.000	.533
Intercept	7049.141	1	7049.141	58.156	.000	.390
Pre-test	6936.065	1	6936.065	57.223	.000	.386
Treatment Groups	6643.184	2	3321.592	27.403	.000	.376
Error	11030.177	91	121.211			
Total	260112.000	95				
Corrected Total	23610.947	94				

a. R Squared = .533 (Adjusted R Squared = .517)

The results in Table 1 showed that there issignificant effect of 5E-cyclic and mental models on students' conceptual understanding of energy concepts in Basic Science $F_{(2, 91)} = 27.403$, $p < 0.05$, partial $\eta^2 = 0.376$. The findings also demonstrated that instructional techniques alone accounted for 37.6% of the variation in students' academic achievement in energy concepts in Basic science. The null hypothesis (Ho_1) was therefore rejected.

The results of post-hoc test for the groups is presented in the table 2.

Based on Estimated Marginal Means.*. The mean difference is significant at the .05 level

Table 2 showed the results of the Bonferroni-corrected post-hoc comparisons conducted to determine where the differences exist among the three groups in this study. It can be observed from the table 2 that students exposed to 5CMIS is statistically significant different from those exposed to TEM ($_P$< 0.05). Also, there is statistically significant different between the students exposed to MMIS and TEM (p < 0.05). Conversely, there is no statistically significant different between students exposed to 5CMIS and MMIS (p > 0.05).

Hypothesis Two (Ho_2): There is no significant main effect of 5E-cyclic and mental models instructional strategies on students' anxiety towards energy concepts in Basic Science.

Table 3
Analysis of covariance of the effect of 5CMIS and MMIS on students' anxiety towards energy concepts in Basic Science

Source	Type III Sum of Square	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	8714.958[a]	3	2904.986	63.379	.000	.676
Intercept	146.346	1	146.34 6	3.193	.077	.034
Pre-test	8094.312	1	8094.312	176.596	.000	.660
Treatment Groups	129.125	2	64.562	1.409	.250	.030
Error	4171.000	91	45.835			
Total	449857.000	95				
Corrected Total	12885.958	94				

a. R Squared = .676 (Adjusted R Squared = .666)

Table 3 showed that there is no significant effect of 5E-cyclic and mental models instructional strategies on students' anxiety towards energy concepts in Basic Sciencein Ondo State F(2, 91) = 1.409, P > 0.05, partial η^2 = .030. The result further revealed that instructional strategy alone contributed 03.0% of the variance in the students' anxiety towards energy concepts in Basic Science. As a result, the null hypothesis (Ho_1) was upheld.

Table 2
Post-Hoc Test of Pair-wise Comparisons of Basic Science Post-test Scores of Students on Treatments

(I) Strategy	(J) Strategy	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference [b]	
					Lower Bound	Upper Bound
5CMIS	MMIS	1.372	2.823	1.000	-5.513	8.256
	TEM	18.161*	2.761	.000	11.427	24.895
MMIS	5CMIS	-1.372	2.823	1.000	-8.256	5.513
	TEM	16.789*	2.747	.000	10.090	23.488
TEM	5CMIS	-18.161*	2.761	.000	-24.895	-11.427
	MMIS	-16.789*	2.747	.000	-23.488	-10.090

Hypothesis Four (H_o3): There is no significant interaction effect of the two instructional strategies and gender on students' conceptual understanding of energy concepts in Basic Science.

Table 4
Analysis of covariance of effect of the two strategies and gender on students' conceptual understanding of energy concepts in Basic Science

Source	Type III Sum of Square	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	14015.019[a]	6	2335.836	18.990	.000	.564
Intercept	6405.193	1	6405.193	52.073	.000	.372
Pre-test	6885.440	1	6885.440	55.978	.000	.389
Treatment	6797.916	2	3398.958	27.633	.000	.386
Gender	924.688	1	924.688	7.618	.007	.079
Treatment* Gender	218.531	2	109.266	.888	.415	.020
Error	10824.286	88	123.003			
Total	258257.000	95				
Corrected Total	24839.305	94				

a. R Squared = .564 (Adjusted R Squared = .535)

The result in Table 4 revealed that there is no significant interaction effects of treatment and gender on students' conceptual understanding of energy concepts in Basic Science, F(2, 88) = .888, P

> 0.05, partial η^2 = .020. The result further revealed the joint contribution of the treatment and gender 02.0% of the variance in the students' conceptual understanding of energy concepts in Basic Science. Therefore, the null hypothesis (Ho_4) is not rejected. The result indicated that there is no interaction effect of 5E-cyclic and mental models instructional strategies and gender on junior secondary school students' conceptual understanding of energy concepts in Basic Science.

Hypothesis Five (H_04): There is no significant interaction effect of the two instructional strategies and gender on students' anxiety towards energy concepts in Basic Science.

Table 5
Analysis of covariance of effects of the two strategies and gender on students' anxiety towards energy concepts in Basic Science

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	9733.6186[a]	1	622.270	32.468	.000	.689
Intercept	112.962	1	112.962	2.261	.136	.025
Pre-test	8434.335	1	8434.335	168.803	.000	.657
Treatment	130.754	2	65.377	1.308	.275	.029
Gender	42.290	1	42.290	.846	.360	.010
Treatment* Gender	106.611	2	53.305	1.067	.349	.024
Error	4396.971	88	49.966			
Total	458457.000	95				
Corrected Total	14130.589	94				

a. R Squared = .689 (Adjusted R Squared = .668)

The result of the two-way interaction effect in Table 5 revealed that there is no significant interaction effects of treatment and gender on students' anxiety towards energy concepts in Basic Science, F(2, 88) = 1.067, P >0.05, partial η^2 = .024. The result further revealed the joint contribution of the treatment and gender 02.4% of the variance in the students' anxiety towards energy concepts in Basic Science.

Therefore, the null hypothesis (Ho_5) is not rejected. The result indicated that there is no interaction effect of 5E-cyclic and mental models instructional strategies and gender on junior secondary school students' anxiety towards energy concepts in Basic Science.

Discussion of Findings

The findings showed that there was significant main effect of 5e-cyclic and mental models' on students' conceptual understanding of energy concepts in Basic Science. The finding is in conformity with Tuna and Kacar (2013), who discovered that students who participated in a learning cycle had superior academic achievement and trigonometry knowledge retention than those in the control group. In addition, the study agreed with Akinwumi and Bello (2015), who asserted that students who are exposed to 5e-cyclic learning strategy scored significantly higher in physics test than those who were not exposed to learning cycle strategy. In the same vain, the findings agreed with Majid and Prahani (2017) who opined that due to the dynamic nature of atomic structure models, students' learning outcomes (perception and imagination) are likely to alter.

Furthermore, results showed that there is no significant effect of 5E-cyclic and mental model's instructional strategies on students' anxiety towards energy concepts in Basic Science in Ondo State. The finding is in line with Ogonnaya, Okafor, Abonyi and Ugama (2016), Seven, Tiryaki and Ceylan (2017) and Oviawe and Lukmon (2017) who provided reports that there are no longer distinguishing differences in the cognitive and affective skill achievements of students in respect to constructivist learning approach. Conversely, the finding is in contrast with Oludipe and Oludipe (2018) who stated that there is a meaningful difference between each method as given above and traditional method on students' academic success in science and technology.

In addition, the result showed that there is no significant interaction effects of treatment and gender on students' conceptual understanding of energy concepts in Basic Science. This finding is consistent with Nwoke, Iwu and Uzoma (2015); Muhammad(2023) and Samaila, Tsong, Masood, and Bervell (2024)who reported that constructivist teaching approach improved students' achievement and removed gender inequality in science and mathematics. The

finding further agreed with Sangodoyin, (2021) and Abdulkareem, (2021),that there was no interaction between gender and teaching approaches on students' fundamental scientific accomplishment.However, this finding was inconsistency with those of Reilly, Neumann and Andrews, (2019) and Wrigley-Asante, Ackah and Frimpong, (2023)who found considerable discrepancies in boys' and girls' academic performance in science areas.The finding is also at variance with previous finding ofArmah, Akayuure and Armah (2021)as reported that boys perform better than girls in sciences but studies from Ullah and Ullah (2019) and Workman and Heyder (2020)as they revealed that girls showed greater performance in science than boys.

Lastly, the result showed that there is no significant interaction effects of treatment and gender on students' anxiety towards energy concepts in Basic Science. This implies that the effect of anxiety on the students' academic achievement in basic science was insensitive to their gender. This finding is in conformity with Ogonnaya, Okafor, Abonyi and Ugama (2016) and Oladejo, et al (2022) who reportedthere was no significant interaction effect between gender and scientific anxiety on students' academic progress in scienceusing constructivist approach. The findings also supported Alebiosun, Bilesanmi-Awoderu, and Oludipe(2017), who found that when both male and female students were taught separation techniques, acids, bases, and salts, water, and balancing chemical equations in chemistry using a constructivist learning approach, their anxiety levels were similar.

ACKNOWLEDGEMENT

Tertiary Education Trust Fund (TETFund), Abuja, Nigeria is acknowledged for research sponsorship

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