Effects of Science Process-Based Method on Creativity among Secondary School Biology Students with Varied Abilities in Zaria, Nigeria

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Abstract

The study, focused on the Impact of Science Process-Based Approach on Creativity among Secondary School Biology Students with Varied Abilities in Zaria, Nigeria," it aimed to determine the effect of teaching methods on students' creativity. Two research questions and two null hypotheses were formulated and tested at a significance level of P≤0.05. A pretest and posttest quasi-experimental design with a control group was employed, involving 133 SSII students from two coeducational secondary schools in Zaria. The experimental group received instruction on living concepts in Biology using Science Process-Based Approach (SPBA), while the control group experienced the Lecture Method. The Creativity Test Questionnaire (CTQ) served as the validated instrument for data collection. Statistical analyses included mean rank, standard deviation, one-way analysis of variance (ANOVA), analysis of covariance (ANCOVA), and Kruskal Wallis. The study findings revealed that students taught using SPBA exhibited significant differences in creativity traits, favoring the high experimental group over the lecture method, and male and female students taught using SPBA performed significantly better in creativity traits, favoring the high female experimental group over the lecture method. In light of these results, the study recommends organizing SPBA training for Biology teachers through workshops to equip them for integrating this approach into lessons, particularly in teaching specific Biology concepts, to enhance students' creativity.

Keywords: Process-based Approach, Creativity, Varied Abilities, Biology, Students

Introduction

The significance of science to humanity, especially in the context of explaining everyday phenomena and technological development, is crucial. Studying science and technology becomes obligatory in the 21st century, where the world is rapidly evolving into a global village. The gains that a nation makes in the fields of science and technology have a substantial impact on the nation's economic, social, and political development. According to Mormina (2019), science is a vital enterprise, utilizing human intelligence to understand nature and natural phenomena better. Science plays profound roles in individual and national life, allowing rational decision-making, the creation of just societies, and understanding the environment. It improves life expectancy, addressing existential problems like disease and hunger. Preston and Haines (2021) underscore the

national contributions of science in various domains such as health, automation, genetic engineering, agriculture, transportation, and construction. Consequently, many countries, including Nigeria, invest substantially in science to harness its individual and national impacts.

Science Processes refer to interconnected activities qualified individuals conduct to explore the universe. As Sarath and Geetha (2020) highlighted the concept of the "process of science" has various interpretations. A programme called Science - A Process Approach (SAPA) is being implemented by the American Association for the Advancement of Science (AAAS). This programme focuses a greater emphasis on science processes and lays less of an emphasis on specific scientific content. Science is characterised by the actions that scientists take, as stated by the Scientific and Philosophical Association of America (SAPA), and science process skills cover a wide range of competencies that are applicable across a variety of scientific fields and represent the behaviour of scientists.

Maranan (2017) categorizes science into two main components: scientific knowledge and knowledge acquisition methods. Scientific knowledge involves theories, principles, and laws, while knowledge acquisition methods consist of science attitudes and process skills. Science attitudes encompass the basic prerequisites for individuals engaging in scientific activities, emphasizing inclination and orientation. Science Process Skills (SPS) facilitate science learning, encourage active student involvement, develop a sense of personal responsibility in self-learning, enhance knowledge retention, and instil investigative attitudes and methods.

Science Process Skills (SPS) are cognitive abilities utilized in problem-solving and drawing conclusions, essential for scientists in their work Maranan, (2017) stated that these skills form the foundation of scientific thinking and research, crucial in understanding the world. According to Ekici and Erdem (2020), scientists possess diverse and significant abilities known as scientific process skills. Okafor (2021) highlights the importance of acquiring process skills in science teaching, emphasizing that it engages students in practical applications, facilitating a deeper understanding of scientific concepts. Despite ongoing efforts to enhance science education, student performance in Nigeria still needs to improve, attributed to negative attitudes toward the subject and inadequate laboratory resources (Jebson & Hena, 2015). The disconnect between theoretical teaching and practical experiences contributes to the need for more acquisition of science process skills, evidenced by mass student failures in public examinations.

Creativity is pivotal in science education, enabling individuals to practically innovate and apply scientific knowledge (Joynes *et al*., 2019). Cultivating creative thinking skills from primary school onwards is essential for students to navigate adult challenges effectively. Scientists leverage Creativity at every research stage, especially in formulating problems and hypotheses and designing experiments. The importance of Creativity in problem-solving has been acknowledged, and its promotion has become a significant educational concern. Recognizing the individual differences among students, especially in terms of creative thinking abilities, is crucial. The biology curriculum in Nigerian secondary schools aims to impart key biological concepts, foster understanding of the world, and develop essential skills. However, students often need to meet these expectations because teachers emphasize theoretical presentations over practical aspects, as Nsofor and Dada (2013) noted. The study highlights the need to include science process skills in science learning assessment, as Harlen and Gadzama (2012) suggested.

Varied ability or ability grouping, involving categorizing students based on academic ability, is explored in this study. Glossenger and Cowell (2021) describe high, average, and low-ability groups, emphasizing the importance of recognizing different levels of student abilities. The study references an experiment by Ridgeway, which used an interactive lecture strategy for basic (low ability) students and lecture-and-note methodology for gifted (high ability) students, resulting in the basic class outperforming the gifted class. The World Health Organization's (2017) definition of gender is introduced, and Ismail *et al*, (2021) discuss gender stereotypes that assume male superiority in science and applied science subjects. The study aims to explore how academic performance can be improved across low-, medium-, and high-ability students using the Science Process-Based Approach teaching strategy.

The study acknowledges that the biological functions of male and female children remain consistent, but cultural influences may impact the reasoning of male and female students differently. The cultural roles assigned to boys and girls can contribute to gender-related differences in learning and science performance. For instance, Mari (2012) conducted a study revealing that science process skills instruction was more effective in enhancing these skills for female students than for males. A study was conducted by Ahmed (2021) to investigate the correlation between the academic results of male and female students in integrated science and their success in practical activities. In terms of academic success in practical activities and overall

academic achievement, the study discovered that there was no significant difference between male and female students with relation to academic performance. In this context, the purpose of the current study is to explore the impact of the Science Process-Based Approach on creativity among secondary school biology students in Zaria, Nigeria, who have a wide range of talents.

In Nigeria, biology holds immense importance and enjoys widespread popularity among students at the senior secondary school level. However, there is a noticeable gap in overall performance, raising concerns regarding potential shortages in the science and technology workforce. One major contributing factor to this issue is the utilization of inadequate teaching methods, notably rote learning, which fails to adequately engage students and hampers their performance in biology at this educational level. The Senior Secondary School Certificate Examination (SSSCE) results for biology students in Kaduna state further emphasize this issue, with consistently less than 50% of students passing at credit level (A1-C6) over the past seven years.

The performance of students can be seen from the statistical table of Biology results in May/June West African Examination S.S.C.E in Kaduna State, Nigeria.

Table 1 Students' Performances in Biology in Kaduna State WAEC May/June, 2011-2017

Year	Total Sat	No with A1-C6	% with A1-C6	No with D7-F9	% with D7-F9
2011	126,821	59657	47.04	67161	52.96
2012	134,852	56570	41.95	78282	58.05
2013	130,653	56155	42.98	74498	57.02
2014	150,925	72204	47.85	78722	52.17
2015	143,936	62008	43.08	81928	56.92
2016	149,162	61028	40.90	88134	59.10
2017	136,916	58284	42.60	78632	57.40

Source: West African Examination Office, Kaduna Office (2017).

The declining trend in academic performance underscores the need for effective interventions that promote activity-based and learner-centred teaching and learning approaches. Current teaching methods, focused on completing the curriculum with an emphasis on passing tests, have yet to yield satisfactory results. Several factors have been suggested for low performance in biology, including teaching methods, learning materials, teaching factors, societal influences, and teacher strategies. This study investigates the impact of the science process-based approach on Creativity among biology students with varied abilities in Zaria, Kaduna.

Purpose of the Study

The study has the following general objectives:

i. To determine the Creativity of varied abilities, biology students were taught using the science process-based approach (SPBA) and lecture method.
ii. To investigate the Creativity of males and females with varied abilities, biology students were taught using the science process-based approach (SPBA) and lecture method.

Research Questions

This study aimed to address the following research questions:

i. What is the difference in the mean scores of Creativity among varied ability students taught Biology using the Science Process Approach (SPBA) and Lecture Method?
ii. What is the difference in the mean scores of Creativity among male and female students of varied abilities taught biology using the Science Process-Based Approach (SPBA) and Lecture Method?

Research Hypotheses

By the research questions, null hypotheses were formulated and tested at the significance levels of $P \leq 0.05$.

$H_{O\,1}$: There is no significant difference in the mean scores of Creativity among varied ability students taught Biology using the Science Process-Based Approach (SPBA) and Lecture Method

H_{O2}: There is no significant difference in the mean scores of Creativity among male and female students of varied ability who were taught biology using the science process-based approach (SPBA) and lecture method.

Methodology

The research utilised a design that was both quasi-experimental and involved a control group with pretest and posttest measures involving two coeducational secondary schools and two classes in Zaria Local Government Area, Kaduna State. Pretests were administered before exposing the experimental group to the Science Process-Based Approach, with schools randomly assigned to

experimental and Control groups. Using the same instrument, posttests were conducted to evaluate the effects of the instructional methods. In accordance with the categorization that Ajewole and Okebukola had developed, the subjects were categorised according to their levels of ability. The target population included 3,929 Senior Secondary Schools II Biology students in Zaria Local Government Area. The sample size, drawn from two coeducational schools, comprised 133 students, 63 in the experimental group and 70 in the control group. The Creativity Test Questionnaire (CTQ), consisting of 89 items on flexibility, originality, fluency, and motivation, was used as the instrument for data collection. The CTQ was assessed utilizing the Split-half reliability method, resulting in a reliability coefficient of 0.76. After a five-week teaching period, a posttest using the CTQ was administered, and data were analyzed using mean, standard deviations, ANOVA, ANCOVA, and KRUSKAL WALLIS to answer research questions and hypotheses.

Results

Research Question 1: What is the difference in the mean scores of Creativity among varied ability students taught Biology using the Science Process Approach (SPBA) and Lecture Method?

Table 2 Mean Rank of Students Creativity Test Scores in Experimental and Control Groups

Ability Levels	Groups	N	Mean Rank	MD
Low	Experimental	16	81.28	62.59
	Control	18	18.69	
Medium	Experimental	31	101.47	66.29
	Control	34	35.18	
High	Experimental	16	122.66	68.77
	Control	18	53.89	

The result in Table 2 revealed that experimental and Control groups for low ability levels have their mean rank of 81.28 and 18.69, respectively, with a mean difference of 62.59. The experimental group has a mean rank value of 101.47 and 35.18 for the medium ability level. In the control group, there was a mean difference of 66.29. Conversely, in the high-ability level, the experimental group displayed a mean rank value of 122.66, compared to 53.89 for the control

group, resulting in a mean difference of 68.77. Thus, the highest mean difference was observed in the high-ability group, at 68.77, while the lowest was recorded in the low-ability group, at 62.59.

Research Question 2: What is the difference in the mean scores of Creativity among male and female students of varied ability taught biology using the Science Process-Based Approach (SPBA) and Lecture Method?

Table 2 Mean Rank Statistics of Male and Female Students Creativity Test Scores in Experimental and Control Groups.

Ability Levels	Groups	Gender	N	Mean Rank	MD
Low	Experimental	Male	7	78.29	5,32
		Female	9	83.61	
	Control	Male	9	21.06	4.73
		Female	9	16.33	
Medium	Experimental	Male	12	99.33	3.49
		Female	19	102.82	
	Control	Male	18	32.39	5.92
		Female	16	38.31	
High	Experimental	Male	10	121.65	2.68
		Female	6	124.33	
	Control	Male	9	53.83	0.11
		Female	9	53.94	

The results in Table 2 reveal that within the experimental group, among students with low ability, there was a performance mean rank score of 78.29 for males and 83.61 for females, indicating a mean difference of 5.92. For students with medium ability, the performance mean rank scores were 99.33 for males and 102.82 for females, showing a mean difference of 3.49. In the high ability category, males and females achieved performance mean rank scores of 121.65 and 124.33, respectively, with a mean difference of 2.68.

In the Control group, among low ability, males and females had performance mean rank scores of 21.06 and 16.33, respectively, with a mean difference value of 4.73; among the Medium ability, males and females had performance mean rank scores of 32.39 and 38.31, respectively with a mean difference of 5.92, while among the High ability male and female had performance scores of 53.83 and 53.94 respectively with a mean difference of 0.11. Hence, the mean difference is greater in the medium ability subgroup of the control group, for both male and female participants, with a value

of 5.92, and lowest in the high-ability subgroup of the control group, for both male and female participants, with a value of 0.11.

Null Hypothesis One (H_{O1}): There is no significant difference in the mean scores of Creativity among varied ability students taught Biology using Science Process-Based Approach (SPBA) and Lecture Method

Table 3 (a) Kruskal Wallis result of Students Creativity in Experimental and Control groups

Ability Levels	Groups	N	Mean Rank	Df	X^2 computed	X^2 critical	P
Low	Experimental	16	81.28	5	114.012	11.07	0.000
	Control	18	18.69				
Medium	Experimental	31	101.47				
	Control	34	35.18				
High	Experimental	16	122.66				
	Control	18	53.89				

$\alpha \leq 0.05$ level of significance

Table 3 (a) showed that among the Experimental and Control groups for low ability levels, mean rank scores are 81.28 and 18.69, respectively. Medium ability has experimental and Control groups' mean rank scores of 101.47 and 35.18, respectively. The Experimental group, particularly those with high ability, demonstrated mean rank scores of 122.66, while the Control group scored 53.89. The computed P value of 0.00 fell below the 0.05 alpha significance level, while the calculated X2 value of 114.012 surpassed the critical X2 value of 11.07 at a degree of freedom (df) of 5. These findings indicate that all three diverse ability groups in the Experimental group demonstrate significantly elevated levels of Creativity compared to their counterparts in the Control group. Consequently, the null hypothesis, which posited no significant difference in the mean creativity scores among varied ability students taught Biology using the Science Process-Based Approach (SPBA) and Lecture Method, is rejected.

Upon interpreting Table 3 (a), it is evident that significant differences exist in the mean creativity scores among varied ability students taught Biology using the Science Process-Based Approach (SPBA) and Lecture Method. A post-hoc test using Scheffe's test was conducted to determine the significance level, as shown in Table 3 (b).

Table 3 (b) Post-hoc Scheffe's Result of Students' Creativity in Experimental and Control groups

Groupings		N	Subset for alpha = 0.05				
			1	2	3	4	5
Low	Experimental	16			141.1875		
	Control	18	115.7778				
Medium	Experimental	31				153.5161	
	Control	34	121.7353	121.7353			
High	Experimental	16					169.8125
	Control	18		128.3333			
	Sig.		.214	.124	1.000	1.000	1.000

The Post Hoc Scheffe test in Table 3 (b) on Mean Rank Creativity scores for varied ability students taught Biology using Science process skills (experimental) and lecture (Control) method revealed distinct patterns. Subset 2 indicated that low Control (115.7778) and medium Control (121.7353) had the lowest Creativity, followed by high Control (128.3333). Moving to subset 3, low experimental (141.1875) emerged next, succeeded by medium experimental (153.5161) in subset 4, and the highest was high experimental (169.8125), with creativity allocated to the highest subset 5. This analysis highlights that the high experimental group displayed the highest level of Creativity, whereas low Control and medium Control exhibited the lowest creativity levels.

Null Hypotheses Two (HO_2): There is no significant difference in the mean scores of Creativity among male and female students of varied ability taught biology using the Science Process-based Approach (SPBA) and Lecture Method

Table 4 (a) Kruskal Wallis result of Male and Female Students' Creativity in Experimental and Control groups

Ability Levels	Groups	Gender	N	Mean Rank	df	X^2 computed	X^2 Critical	*P*
Low	Experimental	Male	7	78.29	11	114.434	19.68	0.00
		Female	9	83.61				
	Control	Male	9	21.06				
		Female	9	16.33				
Medium	Experimental	Male	12	99.33				
		Female	19	102.82				
	Control	Male	18	32.39				
		Female	16	38.31				
High	Experimental	Male	10	121.65				

Ability Levels	Groups	Gender	N	Mean Rank	df	X^2 computed	X^2 Critical	*P*
		Female	6	124.33				
	Control	Male	9	53.83				
		Female	9	53.94				

$\alpha \leq 0.05$ level of significance

Table 4 (a) showed that among the experimental low ability, males and females have mean ranks of 78.29 and 83.61, respectively, while the control group, male and female low ability have 21.06 and 16.33 mean ranks, respectively. In the experimental medium ability, males and females have mean ranks of 99.33 and 102.82, respectively, whereas in the control group, male and female medium ability have mean ranks of 32.39 and 38.31, respectively. In the experimental high ability males and females have a mean rank of 121.65 and 124.33, respectively, whereas the control group male and female high ability have a mean rank of 53.83and 53.94, respectively; it was observed that the calculated P value of 0.000 falls below the 0.05 significance level. Concurrently, the computed X2 value of 114.434 exceeds the X2 critical value of 19.68. This indicates notable disparities in the mean creativity scores among male and female students with varying abilities when instructed using the Science Process-Based Approach (SPBA) and Lecture method. Consequently, the null hypothesis, which suggests no significant difference in the mean creativity scores between male and female students with varying abilities when taught biology using the Science Process-Based Approach (SPBA) and Lecture Method, is refuted. Building upon the interpretation provided in Table 4 (a), the findings unveiled significant differences in the mean creativity scores among male and female students of varying abilities instructed using the Science Process-Based Approach (SPBA) and Lecture method. To further assess the significance level, the data underwent a Post-hoc test utilizing Scheffe's test as outlined in Table 4 (b).

Table 4 (b) post-hoc Scheffe's Result of Male and Female Students Creativity in Experimental and Control groups

Ability Levels	Groups	Gender	N	Subset for alpha = 0.05			
				1	2	3	4
Low	Experimental	Male	7		139.8571		
		Female	9		142.2222		
	Control	Male	9	116.4444			
		Female	9	115.1111			
Medium	Experimental	Male	12			152.2500	

Ability Levels	Groups	Gender	N	Subset for alpha = 0.05			
				1	2	3	4
		Female	19			154.3158	
	Control	Male	18	120.7778			
		Female	16	122.8125			
High	Experimental	Male	10				169.8000
		Female	6				169.8333
	Control	Male	9	128.6667			
		Female	9	128.0000			
	Sig.			.106	.067	.057	1.000

In Table 4 (b), the summary of Scheffe's Post hoc test results on the mean creativity scores among male and female students with varied abilities taught biology using the Science Process-Based Approach and Lecture method reveals distinct patterns. The lowest creativity levels were observed in Female Control low (115.111), male Control low (116.4444), male control medium (120.7778), female control medium (122.8125), female control high (128.0000), and male control high (128.6667), assigned to the lowest subset 1. Transitioning to subset 2, male experimental low (139.8571) and female experimental low (142.2222) were noted. In subset 3, male experimental medium (152.2500) and female experimental medium (154.3148) were identified. Finally, in subset 4, the male experimental high (169.8000) and female experimental high (169.8333) showcased the highest mean Creativity, with the female experimental high attaining the pinnacle of mean creativity levels.

Discussion of Findings

This study investigated the Impact of the Science Process Approach on Creativity among secondary school biology students of varied abilities in Zaria. The study also reveals that the science process-based Approach increased students' Creativity among the varied abilities group in both the experimental and Control groups. This is because the exposure of students to the concepts of living and its relationship with Creativity is encouraging and made students in both groups see the need to marry Creativity and science process skills in the experiments conducted by themselves from the Biology concepts being taught that difference in creativity traits. The finding of this study disagrees with Angulu (2007) and Arokoyo and Nna (2012), who concluded that creative traits enhanced the performance of students with varied abilities.

Significant differences in the Creativity of both males and females found in this study could be attributed to the exposure of the varied abilities groups of both experimental and Control groups to the concept of living being taught during the research. Those students' exposure to the Science Process Approach created a better understanding of the concepts and the creativity skills employed in solving the problems in the concept taught in Biology, enhancing the performance of both males and females in their creative traits. This finding agrees with Angulu (2007), who concluded that creative traits improve both male and female students' academic performance, and Naderi *et al*. (2010), in their findings, indicate that creative traits are related to academic achievement for both males and females. This could be because males and females are given equal opportunity and treatment when SPBA is adopted in teaching Biology concepts.

Conclusion

In conclusion, the SPBA enhanced students' Creativity in all the varied abilities, indicating the effectiveness of SPBA over the Lecture Method in all the varied ability levels. The SPBA enhanced the Creativity of male and female students in all the varied ability groups and favoured the high ability levels in the experimental group, compared with the Creativity of their counterparts in the lecture method.

Recommendations

In light of the study's findings, the following recommendations are proposed:

i. For optimum improvement of students' Creativity, the science process-based Approach (SPBA) should be used in conjunction with one or two other modern teaching methods.
ii. Students' level of Creativity can optimally be improved through constant guidance and direction and should be kept in the hands of peer group influence, which can sometimes lead to reduced positive creativity levels.

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