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MULTIPLE SOLUTION TASKS: AN APPROACH FOR ENHANCING SECONDARY SCHOOL STUDENTS' MATHEMATICAL CREATIVITY

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A B S T R A C T

Background: Inappropriate teaching method adopted by mathematics teachers is one factor responsible for students' poor performance in the subject. Adopting an appropriate method to teaching mathematics that enhances students' performance and boost their creativity in mathematics is a solution. The "Multiple Solution Tasks" is one instructional approach where students are given rich mathematical tasks and are encouraged by teaching how to find multiple solutions or proofs. Finding out the effect of multiple solution tasks instructional approach on students' mathematical creativity is important. **Objective(s):** This study examined the effect of multiple solution tasks instructional approach on students' mathematical creativity in the Njikoka Local Government Area of Anambra State. **Methodology:** The design for this study was quasi-experimental. Two co-educational schools were purposively sampled out for the study. Also, two intact classes of SS2 students were assigned to an experimental and control groups using a simple balloting technique. The study used a sample of 83 SS 2 students (Experimental group – 44 and control group – 39). The data was collected using the Mathematics Creativity Achievement Test (MCAT), which was validated by three experts. MCAT was found to be reliable with the Kuder-Richardson (K-R 20) coefficient of 0.79. The hypotheses were tested using Analysis of Covariance at the 0.05 level of significance, whereas the study questions were addressed using mean and standard deviation. Result(s): The study

A R T I C L E I N F O

Keywords:
Gender; Geometry; Mathematical Creativity; Multiple Solution Tasks.

revealed that the mean creativity scores of students in the experimental groups improved more than those in the control group. Gender as a factor was not found to have a significant influence on students' mathematical creativity. Gender and teaching method did not have a significant interaction effect. **Conclusion:** Multiple solution tasks is an effective instructional approach in booting students' mathematical creativity.

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1. INTRODUCTION

The capacity to come up with innovative, one-of-a-kind solutions to problems or ideas is referred to as creativity. Creativity is said to occur when something that was not existing before or is not common is being created. There are various definitions of creativity by different authors but this study focused on the definitions which are closely related to mathematics. According to Franken (2017), creativity is the ability to generate or recognize ideas, alternatives, or possibilities that can be used to solve problems, engage with people, or entertain ourselves and others. Bishara (2016) describes creativity as a way of learning that permits the learner to make connections between unconnected elements, recognize essential problems, ask questions out of curiosity, be exposed to new ideas, be hesitant to accept regular norms and be flexible and original in categorizing and organizing those norms. Creativity is more than simply using one's imagination; it is also using one's imagination followed by an act of creation. If a person can look at things and circumstances in new ways and from diverse points and perspectives, they are considered to be creative (Bishara, 2016). This implies that a creative individual is a divergent imaginative and innovative thinker in his or her field of study. Employers today are looking for employees with innovative ideas and the ability to handle challenges creatively (Mosimege & Egara, 2022). Mathematicians, educators, and psychologists have explored mathematical creativity from diverse scientific perspectives and recognized its use, as well as the importance of teaching students to appreciate the beauty and originality of mathematics and to explore the world of mathematics (Egara et al., 2018, 2021; Sriraman, 2004). The world, as we know, is rapidly changing. Our current set of talents may become obsolete in the next years. A vital skill is the ability to adapt to new settings and situations. As a result, one of the keys to economic growth in the twenty-first century is innovative thinking. So, how can we best prepare our children for this fast-paced, high-stress environment? To meet the difficulties ahead, this can only be accomplished by boosting the mathematical creativity of future generations.

Mathematical creativity is the ability to construct mathematical objects, as well as the discovery of their reciprocal relationships (Schrauth, 2014). Finding unique ways to solve a subroutine mathematical problem, discovering new theories and finding new proofs to the current theories from different methods, and finding unique ways to solve an uncomplicated mathematical problem are all examples of Mathematical Creativity (Arikan, 2017). When an individual creates a non-standard solution to a problem that can be addressed using a conventional method, they are exhibiting mathematical creativity. Fluency, Flexibility, and Originality are three markers or components of mathematical creativity, according to Siswono (2011). A person's capacity to come up with different responses and solution approaches to a problem is known as fluency in the area of mathematical creativity (Siswono, 2011). To put it another way, an individual's creative fluency is measured by the number of responses they can generate. The evaluator should assess the responses in a test based on their relevance and significance. The number of diverse ways utilized to solve an issue is referred to as flexibility (Siswono, 2011). Though flexibility and fluency are two independent aspects of creativity, they are inextricably linked (Leikin, 2009). Due to the substantial correlation between fluency and flexibility scores, Leikin (2009) highlighted that fluency ratings are excluded from the grading scheme. Leikin went on to say that because fluency has a low link with total creativity, it should not be utilized alone for evaluating mathematical creativity. Fluency and flexibility are dynamic, whereas originality is a gift, according to Leikin (2013). Originality refers to a person's capacity to come up with a solution that is unique and unusual for his or her degree of expertise (Leikin, 2013). As a result, an individual exhibits originality in a mathematical situation when he or she develops a solution that is unusual, unique, or novel. According to Leikin (2009), Originality and Flexibility had a correlation value of almost 1 with creativity. As a result, they can be used to assess creativity on their own. Sriraman (2004) also supports the importance of mathematical creativity, claiming that it ensures the progress of the area of mathematics as a whole.

In Nigerian classrooms, what predominates is the teaching of mathematics using the conventional method which does not allow students to think creatively (Inweregbuh et al., 2020; Okeke et al., 2022a, 2022b).

Therefore, teaching mathematics and creativity overlap. Because of a lack of creative thinking in the mathematics classroom, students memorize procedures without considering how, why, or where they might be used in real life (Nzeadibe et al., 2019, 2020; Osakwe, et al., 2023). Mathematical creativity is a dynamic feature that may be fostered in a wide variety of learners using appropriate instructional methodologies, rather than being a fixed and static attribute of extremely bright individuals (Arikan, 2017). Teachers will not be able to teach learners the entire range of sophisticated mathematical thinking unless they allow students to participate in both the creation and routine reproduction of mathematical ideas (Inweregbuh et al., 2020). As a result, there is a need to look for ways to develop mathematical creativity in students especially in male and female students in Njikoka Local Government Area of Anambra State, Nigeria. Hence the choice of the topic- Effects of multiple solution tasks (MSTs) on secondary school students' mathematical creativity using geometry concepts. Geometry is the branch of mathematics that deals with the study of different shapes and sizes. Tuttuh-Adegun et al. (2010) described geometry as the study of shapes and their properties.

The MSTs are tasks that include a necessity to solve an issue in several ways. The differences in solutions can be reflected in the use of (a) diverse representations of a mathematical concept; (b) diverse properties (definitions or theorems) of mathematical concepts from a particular mathematical topic; and (c) diverse mathematics tools and theorems from various branches of mathematics (Leikin & Levav-Waynberg, 2007). Diverse auxiliary constructions are considered a difference of type (b) in the case of MSTs in geometry. Therefore, MSTs are mathematics problems solved in multiple ways, using different representations, properties or theorems. In MSTs classrooms, students are given rich mathematical tasks and they are encouraged by teaching how to find multiple solutions or proofs.

2. STATE OF THE PROBLEM

The absence of creativity and innovation in the educational system is one major issue impeding the development of creative and inventive minds in Nigerians. Over a century after missionaries introduced education to Nigeria, the country's educational system, from primary to postsecondary, continues to focus on generating administrative personnel for government ministries, parastatals, and the private sector (Mowarin & Tonukan, 2010). Because it focuses on learning where pupils cram and battle to pass, the nation's educational system can be properly termed as 'Certified education.' The goal of this educational system is to obtain a credential rather than knowledge. This antiquated, non-creative, and non-innovative educational system has exacerbated graduate unemployment, as most Nigerian graduates have been locked out of the worldwide labour market due to the growing demand of the modern technologically driven economy.

3. PURPOSE OF THE STUDY

The major goal of this research is to determine the effect of Multiple Solution Tasks (MSTs) on secondary school students' mathematical creativity in Njikoka Local Government Area of Anambra State, Nigeria. Specifically, the study sought to:

1. Investigate the effect of MSTs on the mathematical creativity of SS2 students in experimental and control groups.

2. Determine the effect of MSTs on the mathematical creativity of male and female SS2 students in the experimental group.

3.1 RESEARCH QUESTIONS

The research was directed by the following research questions:

1. To what extent does the mean creativity scores of SS2 students taught geometry using MSTs and those taught same topics using expository method differ?

2. What is the difference between the mean creativity scores of male and female SS2 students taught geometry using MSTs?

3.2 HYPOTHESES

The following null hypotheses were proposed and tested at a significance level of 0.05:

HO1: There is no significant difference between the mean creativity scores of SS2 students taught geometry using the MSTs approach (experimental group) and those taught using expository method (control).

HO2: There is no significant difference between the mean creativity scores of male and female SS2 students in the experimental group.

HO3: There is no significant interaction effect of group and gender as measure by mathematical creativity achievement test.

4. METHODOLOGY

This research used a quasi-experimental approach. The study used a non-randomized pre-test posttest control group design, to be precise. A quasi-experiment is a study in which participants are not randomly assigned to experimental or control groups, but instead are placed in pre-existing groups (Nworgu, 2015). The population of this study was made up of 780 Senior Secondary School Two (SS2) students from the 11 public secondary schools in Njikokai Local Government Area (LGA) of Anambra State (eight co-educational, two girls-only, and one boys-only) (280 males and 500 females). For the study, two co-educational schools were chosen at random. One of the schools was assigned to the experimental group at random, while the other was assigned to the control group. Using simple balloting, one SS2 intact class was allotted to either the experimental or control group out of the arms of SS2 students in each of the sampled schools. The sample consisted of all students from the complete classes, for a total of 83 students from the two institutions. The experimental group had 25 males and 19 females (44) in it, while the control group had 17 males and 22 females (39) in it. Students in the experimental group were taught evidence of certain basic geometric theorems, such as proofs of angles, using a multiple solution problem learning strategy, whereas students in the control group were taught using an expository method. The Mathematical Creativity Achievement Test (MCAT) was utilized to collect the data for the study and functioned as a pre-test (delivered before the start of the treatment) and posttest (given after the treatment) for both the experimental and control groups. It was a four-week experiment.

The Mathematical Creativity Achievement Test (MCAT) was developed by the researchers based on the SS2 Mathematics syllabus covering geometry. It was divided into two sections: section A asked for students' biographical information, while section B had five open-ended questions with numerous answers. Students were needed to offer many solutions to each question, each of which had to be original and distinctive. The instrument was validated by three experts. A pilot test was carried out in Community Secondary School, Obosi in Idemili North LGA of Anambra State. The reliability coefficient of the instrument was obtained to be 0.79 using the Kuder-Richardson formula 20 (K-R20). One correct response (fluency) and one correct strategy (flexibility) were scored five marks each while originality was scored one mark each. Originality was calculated by adding the number of novel ideas (one mark for each novel idea). The creative score was then computed by multiplying each solution's flexibility score by its originality score and then adding the results of the creativity score for all of the student's solutions. Leikin (2009) noted that Originality and Flexibility had a correlation value of almost 1 with creativity. As a result, they can be used to assess creativity on their own. The data for the study was compiled from the pre-test and posttest scores, which were analyzed by means of the SPSS version 23. The mean ($\overline{X}$) and standard deviation (SD) were used to answer research questions, while hypotheses were assessed via Analysis of Covariance (ANCOVA) at a coefficient alpha level of 0.05.

5. RESULTS

The research questions and hypotheses that led the investigation were used to convey the findings. Tables 1 & 2 were used to answer research question 1 while Tables 3 &4 were used in answering research question 2. Tables 5, 6 & 7 were used in testing hypotheses 1, 2, and 3 respectively at a 0.05 level of significance.

Research Question 1

To what extent did the mean creativity scores of SS2 students taught geometry concepts using MSTs and those taught the same concepts using expository method differ?

Table 1: Mean Fluency, Flexibility and Originality scores and standard deviations of the students in the Experimental and Control groups in MCT

Indicators	Groups	N	Pretest		Posttest		Mean Difference	Mean Gain Difference
			$\bar{X}$	SD	$\bar{X}$	SD		
Fluency	Experimental	44	12.80	1.05	23.91	1.14	11.11	8.47
	Control	39	13.21	1.10	15.85	0.93	2.64	
Flexibility	Experimental	44	13.91	1.16	24.82	1.02	10.91	8.71
	Control	39	13.90	1.10	16.10	1.92	2.20	
Originality	Experimental	44	1.50	0.30	2.48	0.27	0.98	0.45
	Control	39	1.43	0.25	1.96	0.57	0.53	

Note: N = number of respondents, $\bar{X}$ *= mean, SD = standard deviation*

In Table 1 above, the mean fluency scores increased from 12.80 to 23.91 (mean gain of 11.11) for the experimental group while the control group increased from 13.21 to 15.85 (mean gain of 2.64). The experimental group had a mean gain difference of 8.47 in their favour. The experimental group's mean flexibility score increased from 13.91 to 24.82, while the control group's score increased from 13.90 to 16.10. The experimental group's mean gain was 10.91, while the control group's mean was 2.20, resulting in an 8.71 mean gain difference in favour of the experimental group. In terms of originality, the experimental group's mean score was somewhat greater than the control group's mean, despite the fact that both were low. Only if a solution is unique inside the instructional group is it regarded original. In the experimental group, the mean originality score increased from 1.50 to 2.48, while in the control group, it grew from 1.43 to 1.96. The experimental and control groups had mean gains of 0.98 and 0.53, respectively, with a mean difference of 0.45 in favour of the experimental group.

Table 2: Mathematical Creativity Demonstrated by the students in the Experimental and Control Groups.

Groups	N	Pretest		Posttest		Mean Gain	Mean Difference
		$\bar{X}$	SD	$\bar{X}$	SD		
Experimental	44	13.35	0.86	24.36	0.81	11.01	8.59
Control	39	13.55	0.86	15.97	1.06	2.42	

Note: N = number of respondents, $\bar{X}$ *= mean, SD = standard deviation*

According to the data in Table 2, the experimental group's pre-test means creativity score was 13.35, while the control group's pre-test means creativity score was 13.55. This indicated that the student's prior knowledge of geometry was pretty similar before the treatment. The experimental group had a mean creative score of 24.36 in the post-test, with a standard deviation of 0.81, while the control group had a mean creativity score of 15.97 in the post-test, with a standard deviation of 1.06. The experimental and control groups had mean gains of 11.01 and 2.42, respectively, with a mean gain difference of 8.59.

Research Question 2

What is the different between the mean creativity achievement scores of male and female SS2 students in the experimental group?

Table 3: Mean Fluency, Flexibility and Originality scores and standard deviations of male and female SS2 students in the experimental group

Indicators	Groups	N	Pretest $\bar{X}$	Pretest SD	Posttest $\bar{X}$	Posttest SD	Mean Difference	Mean Gain Difference
Fluency	Male	25	12.44	0.87	23.80	1.38	11.36	0.57
	Female	19	13.26	1.10	24.05	0.71	10.79	
Flexibility	Male	25	13.52	1.12	24.80	1.19	11.28	0.85
	Female	19	14.41	1.01	24.84	0.76	10.43	
Originality	Male	25	1.49	0.33	2.47	0.27	0.98	0.02
	Female	19	1.50	0.24	2.50	0.29	1.00	

Note: N = number of respondents, $\bar{X}$ *= mean, SD = standard deviation*

From the data in Table 3 above, the mean fluency score of the male group improved from 12.44 to 23.80 (mean gain of 11.36) with a standard deviation of 0.87 and 1.38 respectively, while the mean fluency score improved from 13.26 to 24.05 in the female group (mean gain of 10.79), with a mean gain difference of 0.57 in favour of the male. For the mean flexibility score, the male group improved from 13.52 to 24.80 with a mean gain of 11.28 and females from 14.41 to 24.84 with a mean gain of 10.43. The gain difference of 0.85 was obtained in favour of the male. In the originality, the male mean score improved from 1.49 to 2.77, with a mean gain of 0.98 while the female group improved from 1.50 to 2.50 with a mean gain of 1.00. This showed a mean gain difference of 0.02 in favour of the female group.

Table 4: Mathematical Creativity Demonstrated by the Male and Female Participants in the Experimental Group

Group	N	Pretest $\bar{X}$	Pretest SD	Posttest $\bar{X}$	Posttest SD	Mean Gain	Mean Difference
Male	25	12.98	0.78	24.30	1.00	11.32	0.68
Female	19	13.84	0.71	24.48	0.47	10.64	

Note: N = number of respondents, $\bar{X}$ *= mean, SD = standard deviation*

Table 4 shows that male students' mean creative scores rose from 12.98 to 24.30, while female students' scores improved from 13.84 to 24.48. In addition, the post-test mean scores for male and female students in the experimental group showed that the male and female students improved nearly equally. Male students improved their creativity slightly more than female students. The mean gain difference of the male and female students was 0.68 in favour of the male students. This observation implied that major differences in the improvement in students' creativity could not be attributed to gender. However, the test of the hypothesis will enable the researchers to conclude.

HO_1: There is no significant difference between the mean creativity scores of SS2 students Taught geometry using the MSTs approach (experimental group) and those taught using expository method (control).

Table 5: Analysis of Covariance (ANCOVA) on the mean Creativity Achievement Scores of SS2 Students in Experimental and Control Groups

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Decision
Corrected Model	1455.085a	1	1455.085	1656.383	.000	
Intercept	33640.916	1	33640.916	38294.837	.000	
Group	1455.085	1	1455.085	1656.383	.000	Sig
Error	71.156	81	.878			
Total	36141.000	83				
Corrected Total	1526.241	82				

Note: a. R Squared = .953 (Adjusted R Squared = .953), S = Significant at p<0.05

Table 5 reveals that the calculated F of 1656.383 has a probability of 0.000, which is less than 0.05 the alpha. The implication is that students taught with MSTs and those taught with the explanatory technique in geometry had significantly different mean creativity scores. The experimental group had a higher mean post-test creativity score, as shown in Table 1, and the direction of the difference was in their favour. The null hypothesis of no significant difference was therefore rejected.

HO_2: There is no significant difference between the mean creativity achievement scores of male and female SS2 students in the experimental group.

Table 6: Analysis of Covariance (ANCOVA) on the mean Creativity Achievement Scores of SS2 Students in Experimental and Control Groups

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Decision
Corrected Model	23.946[a]	1	23.946[a]	1.291	.259	
Intercept	34587.801	1	34587.801	1864.888	.000	
Gender	23.946	1	23.946	1.291	.259	NS
Error	1502.295	42	18.547			
Total	36141.000	44				
Corrected Total	1526.241	43				

Note: a. R Squared = .016 (Adjusted R Squared = .004), NS = Not Significant at p<0.05

Table 6 shows the mean creative scores of male and female students in the experimental group, a probability value of 0.259 was found for F = 1.291. As a result, the null hypothesis of no significant difference in mean creativity scores between male and female students was not rejected. Therefore, there was no statistically significant difference in mean creativity achievement scores between male and female students on the MCAT.

HO_3: There is no significant interaction effect of group and gender as measured by mathematical creativity achievement test.

Table 7: Analysis of Covariance (ANCOVA) on the Mean Interaction Effect of Group and Gender as measured by the Mathematical Creativity Achievement Test

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Decision
Corrected Model	1455.411[a]	3	23.946[a]	1.291	.259	
Intercept	33080.541	1	33080.541	36896.066	.000	
Group*Gender	1455.411	3	485.137	541.093	.135	NS
Error	70.830	79	.897			
Total	36141.000	44				
Corrected Total	1526.241	82				

Note: a. R Squared = .954 (Adjusted R Squared = .952), NS = Not Significant at p<0.05

Table 7 showed that the probability value of 0.135 was obtained for F= 541.093 on the interaction effect of MCAT and gender. As judged by the Mathematical Creativity Achievement Test, this means that there was no significant interaction effect between MCT and gender.

6. DISCUSSION

The findings were explained taking into account that though flexibility and fluency are different aspects of creativity, they are strongly related to each order. This is in line with Leikin's (2013) findings that fluency and flexibility are dynamic whereas originality is a gift. The result in Tables 1 & 2 showed that students exposed to a systematic implementation of MSTs in mathematics (experimental group) improved significantly in creativity than those taught using the expository method. This observation corroborated Leikin's (2013) results that MSTs are a useful teaching tool for balancing the degree of mathematical demands in the classroom and achieving students' mathematical potential at various levels. These challenges, according to the author, helped students acquire mathematical knowledge, critical thinking and mental flexibility. Mental flexibility was linked to knowledge and creativity, as evidenced by the substantial improvement in flexibility. After employing MSTs to improve the students' mathematics knowledge and creativity (experimental group), the students had more alternate options for achieving the same goal. The findings pointed to the manner of instruction as a factor in requiring students' creativity in mathematics in general and geometry in particular. The results in Table 2 were corroborated by the ANCOVA results in Table 5, which revealed a significant difference in mean creative ratings between the experimental and control groups, favouring the experimental group. This conclusion corroborated the findings of Star and Newton (2009), who found that addressing problems in a variety of methods increased students' mental flexibility and creativity. More specifically, Kwon, Park and Park (2006) discovered that students who systematically trained using open-ended tasks had a much better mean score on creativity than the control group. The authors concluded that mathematical problems with only one correct answer inhibit students from exploring other ideas, but open tasks like MSTs stimulate and foster creative reasoning. Tables 4 and 6 revealed no significant gender differences in mean creativity scores. In addition, as indicated in table 7, there was no interaction effect between group and gender.

7. CONCLUSIONS

Based on the findings, the researchers established that the exposition of students to MSTs significantly enhanced their mathematical creativity when compared with the expositional method and also that gender as a factor do not play a significant role in students' mathematical creativity with particular reference to geometry.

8. RECOMMENDATIONS

The following recommendations were made as a result of the study's findings:

1. In secondary schools, MSTs should be employed in mathematics teaching and learning especially in geometry;

2. Intensive seminars/workshops and in-service training on the usage of MSTs in mathematics teaching and learning should be provided to secondary school mathematics instructors.

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