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EFFECT OF METACOGNITIVE LEARNING CYCLE ON ACADEMIC ACHIEVEMENT A OF SECONDARY SCHOOL STUDENTS IN MATHEMATICS IN ANAMBRA STATE

Prof. A.M. Osuafor & Chikodili Fidelia Obimezie
Department of Science Education
Nnamdi Azikiwe University, Awka
chikafidelobi@gmai.com

ABSTRACT

The study determined the effect of metacognitive learning cycle on academic achievement of secondary school students in. Two research questions guided the study and six null hypotheses were tested at 0.05 alpha level. The study adopted 2x2 factorial design, specifically, the pretest post-test non-equivalent control group quasi-experimental design. The population of the study consisted of 4, 200 secondary school year one (SS1) students offering mathematics in Ogidi Education Zone of Anambra State. The sample size for the study was 150 SS1 mathematics students obtained using random and purposive sampling techniques. The instrument used for data was Mathematics Achievement Test (MAT) validated by two experts and one experienced mathematics teacher. MAT reliability was established using Kuder Richardson 20 (KR20) to be 0.89. Data relating to the research questions was answered using mean and the hypotheses were tested using analysis of covariance (ANCOVA). The findings of the study revealed that there was a significant difference between the mean achievement scores of students taught mathematics using metacognitive learning cycle and conventional method in favour of metacognitive learning cycle. There was no significant difference between the mean achievement scores of male and female students taught using metacognitive learning cycle. The researcher therefore recommended among others that, mathematics teachers should adopt metacognitive learning cycle in order to cognitively engage students in the learning process and help them integrate previous knowledge in the learning of new mathematical concepts.

Keywords: metacognitive learning, achievement, mathematics

Introduction

Mathematics is a body of knowledge that deals with quantity, structure, size and space. Mathematics is important as a school subject because not only that it is needed for sciences courses but it is also needed for non-science courses at the university. Most secondary and primary schools in Nigeria adopt Mathematics result as a determining factor for promoting students into immediate higher class (Umaru, 2014). Even, most universities in Nigeria insist on credit pass in Mathematics as a prerequisite for admission into any course of study be it science or non-science related course (Joint Admission and Matriculation Board, 2020). There is no doubt that any student who is doing well in mathematics will invariably do well in most science subjects where mathematical knowledge is applied.

The importance of mathematics is made clearer by the assertion of Chinweoke (2011) that any nation seeking scientific and technological development must first address issues of mathematics. Despite the importance of mathematics, students have continually recorded poor performance in mathematics. Evidence from the West African Examination Council (WAEC) statistics on students' achievement in mathematics showed that from 2015 to 2019 showed that the percentage of students who obtained credit pass and above in 2015, 2016 and 2018 is 34.18%, 38.68% and 40.55% respectively, with the exception of 2017 and 2019 result where students showed a slight improvement in their achievement with percentage number students who obtained a credit pass and above being 59.18% and 64.56%. By implication, good number of students do not obtained the required credit pass needed for admission in to universities and if drastic measures are not taken, the story may not change in the future years. (Appendix A, p.111).

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The poor achievement of students in mathematics has been attributed to several factors by researchers. These factors among others include poor teaching strategies use by the teachers, poor teaching materials and test anxiety (Imasuen & Omorogbe, 2015). Experience has shown that many students who record low achievement in mathematics show aversion for mathematics and mathematics related subjects. Some of them according to Umaru (2014) by mere seeing figures or mention of the subject become scared. Gezahegn (2007) attributed students' poor performance in mathematics to lack of adequate learning/study skills. This argument is in consonance with the studies done by Imasuen and Omorogbe (2015) and Anigbo (2016) which showed that most low achieving students do not have effective study strategy that could improve achievement and reduce test anxiety, instead they adopt rote learning method which has been found ineffective for learning complex tasks (Umaru, 2014). The most implicated factor however, is conventional teaching methods/ strategies adopted in teaching mathematics which do not cater for their deeper understanding of the topic.

Conventional method of teaching is a teacher-centered teaching method where the teacher explains the content of learning as an authority and students passively receive the lesson from the teacher. The conventional method does not require or allow so much participation on the part of the students. There has been therefore, a unanimous advocacy for student-centered teaching methods especially now that teaching and learning is emphasizing on active participation of the learners in the learning process. The researcher was poised to investigate the use of student-centered method of teaching that will give the students opportunity for active participation in the learning process especially in mathematics. One of the student centered teaching/ learning strategies is metacognitive learning cycle.

Metacognitive learning cycle is an instructional/ learning strategy that provides the learners an opportunity to reflect on their learning progress at every stage of learning. Hartman (2001) noted that metacognitive learning cycle is appropriate because it is specifically designed to help students progress from concrete to abstract thinking about a concept. According to Offiah (2005), metacognitive learning cycle is of common ancestry as learning cycle, but the basic difference between metacognitive learning cycle and learning cycle is the element of reflection contained in the metacognitive learning cycle. In metacognitive learning cycle, the learners at each phase of the learning experience reflects on the learning thus far in other to assimilate the knowledge they are exposed to and also find out areas of difficulties as well as chart a new plan for integrating knowledge into the memory.

Metacognitive learning cycle stems from the concept of metacognition which anchors on the reflective thinking and cognition. Metacognition is a concept of cognitive psychology that focuses on active participation of an individual in his thinking process. It was first put forward by an American developmental psychologist known as John Flavell in 1976. According to Flavell, metacognition is defined as the knowledge and regulation of cognition. Knowledge of cognition refers to the level of the learners understanding of their own memories, cognitive system and the way the student learns in order to regulate his/her own learning system (Umaru, 2014). Self-regulation is the most remarkable of all the skills and it entails the ability to consciously monitor control and correct one's cognitive activities. Metacognition is a process of making sense, going 'meta' turning around on what one has learned through bare exposure, even thinking about one's thinking is a place to begin. Flavell describes metacognition as a heightened awareness of one's thought process. However, metacognitive learning cycle is a strategy that emphasizes learner's awareness of his thought process in order to ascertain how far he has gone with objectives.

A learning cycle, on the other hands is an inquiring-based teaching approach that can promote critical thinking, active learning and meaningful learning. It was originally developed by Robert Karplus in 1990 to improve learning of science. Learning cycle divides the activities of instruction into four phases. In the first phase, the students are given experience with a concept to be

developed. This experience is called exploration phases. This is followed by conceptual invention (introduction) phase where students and/or teacher derive the concept from the data gathered from the first phase. This is usually carried out as a classroom discussion. The final phase is the application phase where student are given opportunity to explore the usefulness and application of the concepts.

Metacognitive learning cycle is therefore a revised learning cycle proposed by Blank (2000) which incorporates a structured metacognitive element in each phase of instruction. In metacognitive learning cycle, activities of instruction are divided into four phases with addition that the students are asked to reveal and reflect upon the condition or status of their science ideas. The first phase is concerned with the assessment of the given concept, where the students are given opportunity to reflect on the concept to be taught before the lesson began. The second phase is concerned with the exploration of a given concept, where the students are given opportunity to explore materials relating to the topic/concept under study. This is in form of laboratory experiment. The third phase is concerned with the introduction of the given concept, where both the teacher and the students discuss the outcome of the exploration stage. At this phase, the teacher exposes to the students relevant terminologies and other rubrics concerning the topic. The final phase is concerned with the application of the given concept. Here the students are given opportunity to apply the usefulness of what they have learnt.

Each of these phases with the exception of exploration phase is accompanied by metacognitive element in form of status check where students are made to ascertain how well and how far they have learnt by asking themselves thought provoking question which is usually modeled by the teacher. The mathematics teacher, having been equipped with high level of metacognitive strategies, assists in nurturing and training students in metacognitive skills. Researchers such as Elom (2018), Uzobuike (2015) and Andrea (2013) carried out studies in chemistry, physics and biology respectively and revealed that metacognitive learning cycle can be taught to students to improve their learning in those subjects. The question now becomes "Is it possible that such result will be realizable when metacognitive learning cycle is applied in teaching Mathematics concepts in secondary schools in Anambra state?

Mathematics is a subject that requires problem solving and metacognitive learning cycle could help to equip learners with skills in problem solving thereby enabling the learner to assume responsibility for their own learning. When learners take charge of their own learning, they develop confidence in themselves and pursue learning with greater vigour). In metacognitive classroom student consciously reflect on what they are learning. Metacognitive learning cycle encourages critical thinking, promote active learning through frequent questions and provide enough support to allow students to challenge their current conceptions of knowledge and interact with other students (Nwosu, Ebenebe & Unachukwu, 2015). In such classroom, teachers by a way of modeling reflective think aloud, teach the students how to ask themselves better questions in order to ascertain the status of their science ideas. That is, what is known; what is needed to be known and how to go about learning it. Metacognitive skills involve activities such as planning how to approach a given learning task, monitoring comprehension and evaluating progress towards the completion of a task to give feedback. One of such feedbacks is through the academic achievement of the students which is measured using achievement test.

Academic achievement is the learning outcomes of students from what they are taught by their teachers within the classroom (Bahago, 2011).It is the degree of attainment student reaches after being subjected to a period of learning. Achievement usually measured through class assignments, test and examinations conducted by schools and other examination bodies like WAEC and National Examination Council (NECO). Hence, academic achievement refers to accomplishment of academic goals, educational outcomes of students or rather the extent to which a student, a teacher or an instructor have achieved the stated educational objectives. Academic achievement may be influenced by gender.

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In teaching and learning of science and mathematics in particular, issue of gender has been pointed by researchers. Gender is a socio-cultural construct of ascribing characters and roles to sex such as males and females (Oludipe, 2012). The issue of gender in science has resulted into gender bias and gender stereotypes in Nigeria. The stereotyping bias that science is a male enterprise is of great concern in the field of science education and has resulted to a controversial issue and conflicting reports from different researchers. Studies by Ajai and Imoko, (2015); Nzeadibe, Egara, Inweregbuh and Osakwe, (2019) suggested that there exists no significant difference in the achievement and interest of boys and girls in mathematics. Other studies; Anjum (2015); Alordiah, Akpadaka and Oviogboda (2015): Oribhabor (2019) indicated that a significant difference exists achievement and interest of male and female students in mathematics subjects. This study therefore, is also geared towards determining the influence of gender on academic achievement and interest of students in mathematics.

Research Questions

1. What is the difference between the pretest and posttest mean achievement scores of students taught mathematics using metacognitive learning cycle (MLC) and those taught using conventional method (CM)?
2. What is the difference between the mean pretest and posttest achievement scores of male and female students taught mathematics using MLC?

Hypotheses

The hypotheses were tested at 0.05 level of significance.

1. There is no significant difference between the mean pretest and posttest achievement scores of students taught mathematics using metacognitive learning cycle (MLC) and those taught using conventional method (CM).
2. There is no significant difference between the mean pretest and posttest achievement scores of male and female students taught mathematics using MLC.
3. There is no interaction effect of teaching methods and gender on students' achievement in mathematics.

Research Method

The design of the study was non – equivalent pretest-posttest-control group quasi-experimental design, specifically 2x2 factorial design. Specifically, the study adopted the. The study was carried out in Ogidi Education Zone of Anambra state. The population of the study is 4,200 SS1 mathematics students. The sample is made up of 150 senior secondary year one (SSI) mathematics students offering mathematics in Ogidi Education Zone drawn from two secondary schools in the study area. Multistage sampling procedure involving different techniques at each stage was used. First, simple random sampling was used to select two local governments in Ogidi Education Zone. From the two local governments already sampled out, purposive sampling was used to select two co-educational schools that are far apart, one school each from the two local Governments. The reasons behind the selection of the schools are that they are co-educational schools as gender is a variable of interest to the researcher and to avoid class interaction. Random sampling was used to assign the selected coeducational schools into experimental and control group schools. The experimental group school has 79 students (41 males and 38 females) while the control group school have 71 students (37 males and 34 females). The instrument for data collection was Mathematics Achievement Test (MAT). MAT is a 50-item multiple choice test. The instrument was developed by the researcher based on the topics that were taught in this study (basic trigonometry, modular arithmetic and mensuration). A test blueprint was constructed based on the relative emphasis on each of the topics that were taught and this is to ensure that all the cognitive domains of interest are properly captured by the instrument. This was used for pretest and posttest. MAT was validated by two lecturers, one from Department of Science Education and one measurement and evaluation lecturer in the Department of Educational Foundations both from Nnamdi Azikiwe University. The

reliability of MAT was established using Kuder-Richarson 20 (KR-20) to be 0.89. The research work was carried out within a period of six weeks. This period was used for pretest, treatment and posttest. The first week of this study was for school visiting, which involved seeking for permission from school authority to carry out the research work, familiarization with school teachers who were used as research assistants and briefing of these research assistances on how to teach using metacognitive learning cycle for experimental group. The teachers of the various schools taught their students which were selected for this study. In the experimental schools, the teachers taught using metacognitive learning cycle, in the control schools teachers taught using the conventional method. In the second week, pretest was given and treatment commenced in both experimental and control schools according to the school timetable which allocates double period (80 minutes) twice a week for mathematics. The teaching was done in both experimental and control schools using the lesson plans developed for this study. The treatment was given from second week to the fifth week (a period of four weeks). In the sixth week, the students were given a reshuffled MAT and MIS as a posttest. Teachers of experimental group ensured that the students were led through the four phases of metacognitive learning cycle in each topic. Mathematics Achievement Test (MAT) was administered as pretest to both experimental and control groups before treatment. The MAT was reshuffled and was used as posttest. Students were scored according to the marking scheme developed for MAT and the generated scores for both MAT were collected and used for data analysis. The scores collected from pretest and posttest using MAT and MIS were analyzed according to the research questions and hypotheses. The research questions were answered using mean and standard deviation, while hypotheses were tested at 0.05 level of significance using analysis of covariance (ANCOVA). ANCOVA was used to take care of the initial group difference that may exist due to non- randomization of the research subjects at the point of selection into experimental and control group. The decision rule for the hypotheses is that, where p-value is less than 0.05, the null hypothesis was rejected but if it is greater than or equal to 0.05 the hypothesis was not rejected.

Presentation of Results

Research Question 1: What is the difference between the pretest and posttest mean achievement scores of students taught mathematics using metacognitive learning cycle (MLC) and those taught using conventional method (CM)?

Table 1: Mean Achievement Scores of Students taught Mathematics using Metacognitive Learning Cycle and Conventional Method

Source of Variation	N	Pretest Mean	SD	Posttest Mean	Posttest SD	Gained Mean
MLC	79	28.89	5.74	65.52	8.57	36.63
CM	71	30.77	5.92	52.85	6.52	22.08
Difference in Mean		-1.88		12.67		14.55

Table 1 shows that the students taught mathematics using MLC has pretest mean achievement score of 28.89 and posttest mean achievement score of 65.52 with gained mean achievement score of 36.63, while those in the control group taught with conventional method had pretest mean achievement score of 30.77 and posttest mean achievement score of 52.85 with gained mean 22.08. The difference between the gain in mean achievement scores of the group taught using MLC and the group taught using CM is 14.55 in favour of MLC.

Research Question 3: What is the difference between the mean pretest and posttest achievement scores of male and female students taught mathematics using MLC?

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Table 2: Mean Achievement Scores of Male and Female Students taught Mathematics using Metacognitive Learning Cycle

Gender	N	Pretest Mean	SD	Posttest Mean	Posttest SD	Gained Mean
Male	41	29.37	5.89	66.17	8.640	36.80
Female	38	28.37	5.60	64.82	8.555	36.45
Difference in Mean		1.00		1.35		0.35

Table 2 shows that the male students taught mathematics using MLC has pretest mean achievement score of 29.37 and posttest mean achievement score of 66.17 with gained mean achievement score of 36.80, while those in the females had pretest mean achievement score of 28.37 and posttest mean achievement score of 64.82 with gained mean 36.45. The difference between the gain in mean achievement scores of the male and female students taught mathematics using MLC is 0.35 in favour of males.

Hypothesis 1: There is no significant difference between the mean pretest and posttest achievement scores of students taught mathematics using metacognitive learning cycle (MLC) and those taught using conventional method (CM).

Table 3: ANCOVA on Significance of Difference between the Mean Achievement Scores of Students taught Mathematics using MLC and Conventional Method

Source of variation	SS	Df	MS	F	P-value	Decision
Corrected Model	6100.798[a]	2	3050.399	52.076	.000	
Intercept	16494.427	1	16494.427	281.591	.000	
Pretest	94.375	1	94.375	1.611	.206	
Method	6092.493	1	6092.493	104.010	.000	S
Error	8610.642	147	58.576			
Total	546106.000	150				
Corrected Total	14711.440	149				

Table 3 shows that at 0.05 level of significance, there was a significant main effect of the teaching methods on students' achievement in mathematics, F (1, 149) = 104.010, P(0.000) < 0.05. Therefore, the null hypothesis was rejected. Thus, there is a significant difference between the mean pretest and posttest achievement scores of students taught mathematics using metacognitive learning cycle (MLC) and those taught using conventional method (CM) in favour of MLC.

Hypothesis 3: There is no significant difference between the mean pretest and posttest achievement scores of male and female students taught mathematics using MLC.

Table 4: ANCOVA on Significance of Difference between Mean Achievement Scores of Male and Female Students taught Mathematics using MLC

Source of variation	SS	Df	MS	F	P-value	Decision
Corrected Model	150.307[a]	2	75.153	1.024	.364	
Intercept	10373.487	1	10373.487	141.302	.000	
Pretest	114.101	1	114.101	1.554	.216	
Gender	25.604	1	25.604	.349	.557	NS
Error	5579.415	76	73.413			
Total	344856.000	79				

Corrected Total	5729.722	78

Table 4 shows that at 0.05 level of significance, there was no significant main influence of gender on students' achievement in mathematics, F (1, 78) = 0.349, P(0.557) > 0.05. Therefore, the null hypothesis was not rejected. Thus, there is no significant difference between the mean pretest and posttest achievement scores of male and female students taught mathematics using MLC.

Hypothesis 5: There is no interaction effect of teaching methods and gender on students' achievement in mathematics.

Table 5: ANCOVA on Significance of Interaction Effect of Teaching Methods and Gender on Students' Achievement in Mathematics

Source of variation	SS	Df	MS	F	P-value	Decision
Corrected Model	6257.252[a]	4	1564.313	26.830	.000	
Intercept	15480.766	1	15480.766	265.515	.000	
Pre	125.526	1	125.526	2.153	.144	
Method	6137.936	1	6137.936	105.273	.000	
Gender	142.009	1	142.009	2.436	.121	
Method * Gender	21.111	1	21.111	.362	.548	NS
Error	8454.188	145	58.305			
Total	546106.000	150				
Corrected Total	14711.440	149				

Table 5 shows that at 0.05 level of significance, there was no significant interaction effect of teaching method and gender on students' achievement in mathematics, F (1, 49) = 0.362, P(0.548) > 0.05. Therefore, the null hypothesis was not rejected. Thus, there is no significant interaction effect of teaching methods and gender on students' achievement in mathematics.

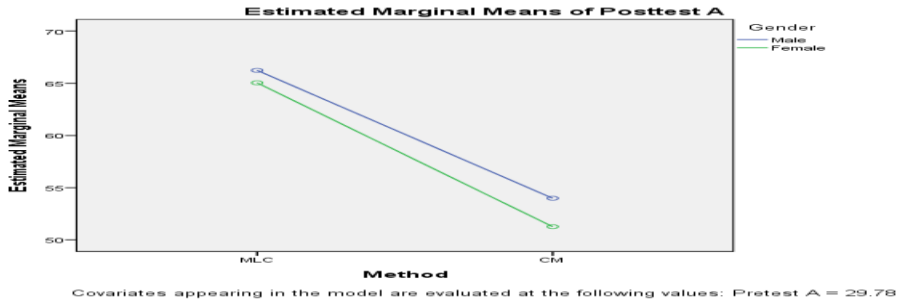


Figure 5: Plot of interaction effect of teaching methods and gender on students' achievement in mathematics

Discussion of Findings

The finding of the study revealed that a significant difference exist between the mean achievement scores of students taught mathematics using metacognitive learning cycle and those taught using conventional method (CM) in favour of metacognitive learning cycle. MLC proved more effective than conventional method because it provides for the students the opportunity to be actively engage in the learning process by thinking critical about the solutions to mathematical problems. Given that the teacher models for the students how to think by thinking aloud during classes, students developed skills of that helped them in each learning phase to integrate previous knowledge in a way that made them understand the concepts taught. The reflective thoughts at the different phases of the learning cycle also enable students to be

responsibly involved in the learning by seeking to understand for themselves. The progress at each stage of the learning was easily evaluated by the students themselves as they think about how much they can solve the mathematical problems.

The enhancement of mathematics achievement by MLC could also be attributed to the fact that MLC exposed students' area of difficulties. With the difficulties noted, students charted out new plans for integrating knowledge into memory as they monitor their progress in learning the new concepts. The cross thinking and rethinking of their success at every stage of their learning experience helped the students to progress from concrete to abstract thinking about learning contents. By cognitively engaging in the learning process and discovery solutions for themselves about mathematical problems, students enhanced their cognitive ability to solve other related problems resulting in improved achievement in mathematics.

The finding of the study is related to the findings of Jegede and Awodun (2013) that metacognition was significant in improving students' achievement in physics. The finding of the study also support the finding of Şahin and Kendir (2013) that that the experimental group taught using MLC had significantly higher posttest scores when compared to the control group. The findings of Tuna and Kaçar (2013) that the experimental group students' scores of academic achievement and permanence of trigonometric knowledge are higher than those in the control group support the findings of the study. The findings of Akinwumi and Bello (2015) that students in the experimental groups taught using metacognitive learning cycle gained higher scores than those in the control group also supports the findings of the study. The finding of Offiah and Akusoba (2009) is at contrast with the finding of the study when they reported that that metacognitive learning cycle (MLC) did not yield significant superiority in improving students' understanding of chemistry concept than traditional lecture laboratory type approach (TLLT).

The finding of the study showed that male and female students taught mathematics using metacognitive learning cycle did not differ in their achievement scores. This was because the metacognitive learning cycle affected the learning of both male and female students in an almost similar way. Both the male and female students were actively engaged in reflective thinking about the solutions and their progress in the learning process. The findings of the study contravene the findings of Elom (2018) that gender has significant effect on students' academic achievement when taught physics using metacognitive learning cycle model as female students showed higher mean gain score. The finding of the study on achievement is also in line with the findings of Okonkwo (2016) that gender was not a significant factor in students' achievement in basic science. The finding of the study was also not in line with the finding with the finding of Onyedike (2011) that gender has a significant impact on students' academic achievement when taught in metacognitive classroom environment as male students manifested better academic achievement.

Conclusion

The conclusion drawn from the findings of the study is that metacognitive learning cycle is effective for improving students' achievement in mathematics. The study concludes that the use of MLC engages students actively in the learning process in a way that enhances achievement.

Recommendations

The following recommendations were made based on the findings and findings and conclusion of the study.

1. Mathematics teachers should adopt metacognitive learning cycle in order to cognitively engage students in the learning process and help them integrate previous knowledge in the learning of new mathematical concepts.
2. Workshop and seminars should be organized for mathematics teachers by Ministry of Education and other such educational agencies and stakeholders to acquaint them with the strategy of MLC and how to use it in the classroom for teaching mathematics.

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