Metacognition and senior secondary students' learning achievement in Solid Geometry

WONU, Nduka[1] and CHARLES-OGAN, Gladys[2] (Phd)

1. *Department of Mathematics/Statistics, Faculty of Natural and Applied Sciences Ignatius Ajuru University of Education, Port Harcourt, NIGERIA*
2. *Department of Curriculum Studies and Educational Technology, Faculty of Education University of Port Harcourt, Choba, NIGERIA*

ABSTRACT

The effect of Metacognitive Instructional (MCI) model in enhancing the learning achievement of senior secondary students in solid geometry in Emohua Local Government Area of Rivers State was explored in this study. The quasi-experimental design was used. A total of 58 Senior Secondary School I (SSSI) students participated in the study. The instrument used for data collection was a 50-item multiple-choice test, Solid Geometry Achievement Test (SGAT). The Kuder-Richardson, KR-21 method was used to determine the reliability of the instrument to obtain an index of 0.84. Three research hypotheses guided the study. The findings of the exploration established that metacognitive instructional model was effective in the enhancement of the learning achievement of students in solid geometry. Both the male and the female students benefited from the experiment but the female students of the experimental group benefited most. The interaction effect of instructional models and sexwas not statistically significant over learning achievement of senior secondary students in solid geometry. The study recommended among others that mathematics teachers should try to implement the MCI model in teaching mathematics as it was found to improve the learning achievement of senior secondary students in solid geometry.

Keywords: *Metacognition, Model, learning achievement, and Solid geometry*

1.0 INTRODUCTION

Mathematics is very important in the development of any nation. Scientific and technological breakthrough of any nation would be a mirage without mathematical inputs. This might the reason mathematics is made compulsory at the primary and secondary levels of education in Nigeria. Notwithstanding the importance of mathematics in national development, mathematics performance of students in the West African Senior Secondary Certificate Examination (WASSCE) has not been encouraging(Uloko and Imoko, 2007, Wonu & Anaekwe, 2014). This underachievement achievement of students in mathematics has been linked with inappropriate instructional models (Ogunkunle 2009). It is believed that when students are taught mathematics effectively using innovative instructional models, their performance in the subject will improve. Innovative instructional models based on the constructivist theory of Jean Piaget are capable of advancing the understanding of students in mathematics. Metacognitive Instructional (MCI), Model, Teaching for Understanding (TfU) and Systems Analysis Model (SAM) are some examples of the instructional models based on the constructivist theory of learning. However, themetacognitive instructional model is the focus of the present study.

Metacognition was first introduced by John Flavell (1976) based on the concept of metamemory. Metacognition can be defined as thinking about thinking. It entails the conscious awareness and self-regulation of a learner's thought process while trying to solve a problem. According to Brown (1987), metacognition is subdivided into two categories, namely knowledge of cognition and regulation of cognition. The knowledge of cognition entails conscious reflection on individual's thinking abilities whereas regulation of cognition involves the self-regulatory activities at the time of learning or problem-solving The metacognitive regulation of cognition is also regarded as the metacognitive skills, viz: prediction, planning, monitoring and evaluation skills (Brown 1987). These problem-solving skills form the strategic components of the metacognitive instructional model.

The prediction component helps a learner to forecast the complexity of a problem; the planning skill aids the students to analyse the task, identify vital unique skills and effectively organise the critical thinking episode. Monitoring skill aid students to follow the organisedsequence planned to ensure whether the plan is useful in solving the specific problem or not. The evaluation skills are normally placed at the end of the problem-solving exercise to enable students to assess the solution and the steps taken to solve theproblem (Bayat& Tarmizi, 2010). Metacognition has been found to be effective in advancing the learning outcome of students in mathematics (Ogunkunle & Wonu, 2012,Wonu2012).

Desoete (2007) study on evaluating and improving mathematics teaching and learning through metacognition established among others that think aloud protocol analyses were anaccurate but time-consuming approach to quantify metacognitive skills of learners having anadequate level of verbal fluency. Metacognitive skills as quantified by teacher ratings accounted for 22.2% of the mathematics performance of the students. Literature indicated that metacognition was found to improve through training and is effective in advancing the learning of the young learners in problem-solving. Similarly, the study of Çalişkan and Sünbül (2011) on the efficacy of learning instruction on metacognitive skills, metacognitive knowledge and achievement established that students' awareness and metacognitive knowledge improve overtime. Metacognitive skills were also found to be enhanced and its adoption advanced learning.

Özsoy and Ataman, (2009) explored the effect of metacognitive strategy training on mathematical problem-solving achievement among students and the findings among others were that students in the experimental group significantly advanced in metacognitive skills and mathematical problem-solving achievement. Cognitive strategies and metacognitive strategies during algebra problem-solving among undergraduates was explored by Bayat and Tarmizi (2010) and the findings had it that the overall performance of the students significantly correlated with their performance in problem-solving in algebra. The association between overall metacognitive strategies and algebra problem-solving as well as the relationship between overall metacognitive strategies and overall performance were moderately significant and positive. Nett, Goetz, Hall and Frenzel (2012) studied the use of ametacognitive strategy for the exploration of students' learning-related cognition prior to in-class achievement assessment. The study established that metacognitive strategy significantly advanced as the test date approached and monitoring skills were found to have apositive relationship with test performance out of three metacognitive skills assessed.

The effect of gender on the learning achievement of students in mathematics is vital. Abiam and Odok (2006) found no significant relationship between gender and achievement in number and numeration, algebraic processes and statistics. Charles-Ogan (2014) investigated the effects of metacognitive instructional model on senior secondary students' mathematics misconceptions in Rivers State. The findings of the study established that metacognition was capable of reducing misconceptions of students in mathematics. The female students who were taught using metacognitive instructional model had fewer misconceptions when compared with their male counterparts. The mathematics misconceptions of the female students were found to be fewer than that of their counterparts in both groups compared. Wonu (2012) investigated the effect of themetacognitiveinstructional model on the learning achievement of students with developmental dyscalculia in number and numeration. The result established that metacognitive instructional model enhanced the metacognitive skills of junior secondary students and also improved their performance in mathematical problem-solving over time. Gender factor was not significant in the students' learning achievement and the interaction effect between instructional models and gender on thecognitive achievement of students was not also significant. Wonu, and Ogunkunle (2015) explored the effects of metacognitive strategy on the planning skills in number and numeration of students with developmental dyscalculia. The findings of the study had it that students taught using metacognitive instructional model outperformed their counterparts taught using problem-solving strategy over metacognitive planning skills, but the observed mean difference in planning skills was not statistically significant at .05 alpha level. There was no significant difference in the mean metacognitive planning skills between the male and female students taught using the metacognitive instructional model. The interaction effect between strategy and gender was not also significant over students' achievement in number and numeration.

1.1 Statement of the problem

It is no more news that the underachievement of students in mathematics is a recurring decimal. The students who are supposed to be the future leaders of the nation's societal sectors appear to be deficient in critical thinking skill. They seem to lack the higher-order mathematics skills that lead to independent thinking. Stakeholders in mathematics education have been making efforts to enhance the learning mathematics among students, but these efforts have not yielded enough results. Different instructional models have been adopted by teachers to help students learn mathematics. Most of these studies were conducted using instructional models that do not give the students autonomy to self-regulate their thinking process while solving mathematical tasks and most of the studies were conducted outside Rivers State. In line with the foregoing, the present study is a peer into the effectiveness of themetacognitive instructional model in advancing the solid geometry achievement of senior secondary students in Emohua Local Government Area of Rivers State, Nigeria.

1.2 Aim and objectives of the study

The main aim of the present study was to investigate the effectiveness of metacognitive instructional model in advancing the learning achievement of senior secondary students in solid geometry in Emohua Local Government Area, Rivers state, Nigeria. Specifically, the objectives of the study were to:

1. Determine the effect of metacognitive instructional model on the learning achievement of senior secondary students in solid geometry
2. Explore the relative main effect of sex on the learning achievement of senior secondary students taught solid geometry using MCI model and those taught using Problem-based Learning (PbL) model
3. Investigate the interaction of treatments and sex on the learning achievement of senior secondary students in solid geometry

1.3 Hypotheses

To guide the study the following null hypotheses were tested at .05 alpha level.

H_{01}: There is no significanteffect of metacognitive instructional model on the learning achievement of senior secondary students in solid geometry

H_{02}: There is no significant relative main effect of sex on the learning achievement of senior secondary students taught solid geometry using MCI model and those taught using PbL model

H_{03}: There is no significant interaction of treatments and sex on the learning achievement of senior secondary students in solid geometry

2.0 Methodology

2.1 Research design

The study adopted the quasi-experimental design. The dependent and independent variables were learning achievement and instructional models. The design of the study was symbolically represented as shown inTable 1.

Table 1: Research design

Group	Pre-test	Treatment	Post-test
E	O_1	X_{MCI}	O_2
C	O_1	X_{PbL}	O_2

SGAT: Solid Geometry Achievement Test

O_1 = Pre-SGAT, O_2 = Post-SGAT,

E= Experimental group X_{MCI} = Metacognitive Instruction (MCI)

C = Control group X_{PbL} = Problem-based learning (PbL)

2.2 Sample and sampling technique

A total of 58 SSSI students participated in the study. The criteria for the selection of schools in the study were:public senior secondary schools,co-education, presence of qualified graduate mathematics teachers, conceptspreviously taught in the school and registration of students for the SSCE. Two senior secondary schools were purposively selected for participation. Out of the two selected schools, only one arm of SSSI class was assigned to the experimental group while one arm of SSSI class in the second school was assigned to the control group. A total of 28 students (17 males & 11 females) took part in the experimental group and 30(12 males & 18 females) students participated in the control group (C).

2.3 Instrumentation

A researcher, designed and validated instrument titledSolid Geometry Achievement Test (SGAT) was used for data collection in this study. The SGAT consisted of 50 multiple-choice questions/items with four options lettered A to D to be marked over 100 (i.e each correct option carries 2 marks). Three options are distracters and only one option is the correct answer. It is based on five content areas in solid geometry for SSSIstudents(total surface area and volume of solid shapes (cone, cylinder, cuboid, a cube, triangular and rectangular prism, pyramids) frustum of cone and pyramid and composite solids. The reliability of the SGAT was established using the Kuder-Richardson, KR-21 reliability method to obtain an index of 0.84.

2.4 Experimental procedures

The researchers gave the teachers intensive training on the practical and the theoretical aspects of themetacognitive instructional model. Prior to the instructions in the groups, the researchers and the mathematics teachers in each group administered copies of the SGAT to the students as apre-test and gave them time to attempt the questions. The Pre-SGAT scripts were retrieved from the students when completed.

The experimental group: To encourage the development of metacognitive problem-solving skills, the participants in this group were asked to go through the 50 questions on SGAT and work in accordance with a metacognitive assessment worksheet provided to each of them. After the implementation of Pre-SGAT, the metacognitive strategy instruction with problem-solving wasimplemented for the development of the student metacognitive skills. The regulation component of metacognition was used to design the worksheet. The students were trained on the theoretical and practical application of the learning strategy in accordance with their level. They were shown the metacognitive table and how to use it while solving problems during classes. Each problem was presented to the students throughout the lesson period in form of worksheet. The metacognitive strategy skills to be learnt by the students were included in the worksheet. The students were therefore encouraged to work in accordance with the stages included in the worksheet. The large group, small group and individual sessions were adopted. During these activities, the role of the teacher was to supervise the operations and guide the students by asking probing questions that ignite students' critical thinking skill and metacognitive thinking as well as make the process proceed smoothly. By the end of the instructions,Post-SGAT was administered to the students. The scripts were collected, marked and scored over 100.

Control group**:** The strategic components of the PbL model used were problem study, planning, solution plan execution, evaluation and development. At the *problem study*stage, the teacher aided the students to understand the problem to be solved and identify the needs. The teacher goes further to disclose the *plan or process* that leads to the solution of the confronted mathematical task while the students pay attention and jotting down some key points. To *execute the plan*, the problem was solved by the teacher while also explaining some of the procedures used to obtain the solution whereas the students observed what was done at each stage to get the problem solved and attempted to solve the problem. The teacher *evaluated* the solution. To do this, students were assisted in assessing the solution. This was done to ascertain that the plan was executed correctly during the execution stage and for the students to have anin-depth understanding of the procedures that led to the solution of the problem. The teacher finally applied the solution process to solve thereal life mathematical problem at the *development* stage.

2.5 Data analysis

The Analysis of Covariance (ANCOVA) and line graph were used for data analyses.

3.0 RESULTS

Table 2A: Summary of factorial design ANCOVA on the difference in the learning achievement of students in solid geometry based on treatment, sex and interaction

Source	Sum of Squares	df	Mean Square	F	p-value	η^2
Pre-SGAT	5.185	1	5.185	.123	.728	.002
Treatment	217.453	1	217.453	5.140	.027	.088
Sex	65.184	1	65.184	1.541	.220	.028
Interaction	20.613	1	20.613	.487	.488	.009
Error	2242.232	53	42.306			
Total	151216.000	58				
Corrected Total	2593.655	57				

a. R Squared = .135 (Adjusted R Squared = .070), *Key:* η^2 *=Partial eta squared for Cohen effect size*

The result on Part A of Table 2established that there was thesignificant main effect of themetacognitive instructional model on the learning achievement of students in solid geometry (F=1, 53=5.140, p=.027, η^2 =.088). The H_{01} was rejected at .05 alpha level. The Table 2 further showed that there was no significant relative main effect of sex on the learning achievement of students taught solid geometry using MCI model and those taught using PbL (F1, 53=1.541, p=.220, η^2=.028). TheH_{02} was upheld at .05 level of significance. The interaction between treatment and sex was not significant (F1, 53=.487, p=.488, η^2=.009). The H_{03} was also upheld at .05 alpha level.

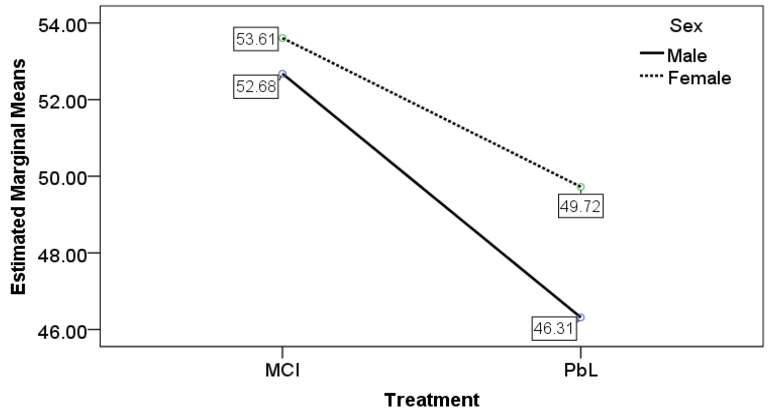

Fig. 1: Plot of interaction between treatment and sex using Estimated Marginal Means of Post-SGAT scores

Covariates appearing in the model are evaluated at the following values: Pretest = 30.8276

The result from Figure 1 shows that the estimated marginal mean Post-SGAT score of the male students taught using MCI model was 52.68 whereas that of their male counterparts taught using the PbL model was 46.31. The estimated marginal mean Post-SGAT score of female students taught using MCI model was 53.61 whereas that of their female counterparts taught using PbL was 49.72.

Table 2B: Simplemain effect analysis on the learning achievement of students in solid geometry

	Independent variable	SS	df	MS	F	p-value	η^2
Sex	MCI	2.508	1	2.508	.156	.697	.006
	PbL	75.850	1	75.850	1.124	.298	.040

MS=*Mean Square* ***SS***= *Sum of Squares*

The part B of Table 2 further shows that the male and the female students taught using the MCI(F=.156, p= .697, η^2=.006), and PbL (F=1.124, p= .298, η^2 =.040) respectively did not differ significantly in solid geometry learning achievement.

4.0 DISCUSSION OF FINDINGS

The discussion of findings of the study was done under the following subheadings:

4.1 Metacognitive instructional model and learning achievement of senior secondary students in solid geometry

The result from Part A of Table 2 showed that metacognitive instructional model impacted significantly on the learning achievement of students in solid geometry (F=1, 53= 5.140, p=.027, η^2 =.088). This necessitated the rejection of H_{01} at .05 alpha level. Figure 1 also shows that students who were taught using MCI model outperformed their counterpartsin the Post-SGAT. This superiority of MCI model over PbL in the Post-SGAT scores may be linked with the self-regulatory aspects of metacognition which enabled the participants in the experimental group to predict the difficulty of the mathematical tasks, plan the problem-solving steps, monitor personal progress with the assistance of the teacher and evaluate the outcome. This is in agreement with an earlier study by Özsoy and Ataman (2009) who investigated the effect of metacognitive strategy training on the mathematical problem-solving achievement among students and establishedthat student who adopted metacognitive instructional model significantly advanced in metacognitive skills and mathematical problem-solving achievement.

4.2 Metacognitive instructional model and gender associated learning achievement of senior secondary students in solid geometry

The result from Figure 1 showed that the observed variance in the estimated marginal mean of Post-SGAT score between the male and female students taught using MCI model was 0.93 in favour of the female students whereas the estimated marginal mean of Post-SGAT score between the male and female students taught using the PbL model was 3.41 also in favour of the female students. When put to thestatistical test the result from Part A of Table 2 showed that there was no significant main effect of sex on the learning achievement of senior secondary students taught solid geometry using MCI model and those taught using PbL (F1, 53=1.541, p=.220, η^2 =.028). TheH_{02} was upheld at .05 level of significance. The Part B of Table 2 further showed that the male and the female students taught using the MCI (F=.156, p= .697, η^2=.006), and PbL (F=1.124, p= .298, η^2=.040) respectively did not differ significantly in solid geometry learning achievement. The findings of the present study are in agreement with an earlier finding byAbiam and Odok (2006) which found asignificant relationship between gender and achievement in number and numeration, algebraic processes and statistics. A similar study by Wonu (2012) also found that gender factor had no significant impact on the learning achievement of students in number and numeration.

4.3 The interaction of treatments and gender on the learning achievement of senior secondary students in solid geometry

The result from Fig. 1 also established that the male students who were taught using MCI model outperformed their male counterparts who were taught using PbL with estimated marginal mean Post-SGAT score of 6.31 whereas the female students who were taught using the MCI model also outperformed their female counterparts who were taught using PbL model with estimated marginal mean Post-SGAT score of 3.89. The experiment appears to be most beneficial to the female students taught using the MCI model. However, the observed negligible difference in the mean score (Mean=0.93) between the male and female students taught using MCI model established the fact that students of both sexes in the experimental group may have collaborated effectively in their respective small groups while solving problems. This further indicated that metacognitive instructional model is capable of eliminating gender inequity in mathematics learning when effectively implemented. When put to thestatistical test, the result from Part A of Table 2 shows that the interaction between treatment and sex was not significant (F1, 53=.487, p=.488, η^2=.009). The H_{03} was also upheld at .05 alpha level. This is evident in the fact that the learning achievement mean score of the male and the female students were almost parallel to each other. Since there was no significant interaction, the effect of themetacognitive instructional model was found to advance the learning achievement of both male and female students irrespective of the fact that the achievement of the female students was found to bebetter than that of the male students in both groups. Generally, the findings further suggest that the achievement of the students taught using MCI model was significantly better than that of the control group irrespective of gender. The present findings arein agreement with Wonu (2012)which found no significant interaction effect between instructional models and gender on learning achievementof students in number and number.

5.0 CONCLUSION

The study has established that metacognitive instructional model was effective in the enhancement of the learning achievement of students in solid geometry. The estimated marginal mean Post-SGAT score indicated that the achievement of theexperimental group was significantly better than that of the control group irrespective of gender but more beneficial to the female students in the experimental group. The MCI was more accommodating in terms of maintaining negligible achievement gap between male and female students in solid geometry. The implication of this finding is that MCI model is capable of closing the existing achievement gap between male and female students in mathematics learning when effectively implemented by the mathematics teachers. The interaction of treatment and sex was not statistically significant over learning achievement of senior secondary students in solid geometry.

6.0 RECOMMENDATIONS

Based on the findings of the study the following recommendations were made:

1. Mathematics teachers should try to implement the MCI model in teaching mathematics as it was found to improve the learning achievement of senior secondary students in solid geometry. The

MCI model gives students the opportunity to predict the outcome of their engagement, plan the solution steps, monitor personal progress and evaluate the results.

2. To close the gender gap in mathematics learning achievement, students of both sexes should be equally engaged in the learning of mathematics.

REFERENCES

1. Abiam, P. O. & Odok, J. K. (2006). Factors in Students' achievement in different branches of secondary school Mathematics. *Journal of Education and Technology.* 1(1), 161 – 168.

2. Bayat, S. & Tarmizi, R. A.(2010). Assessing cognitive and metacognitive strategies during algebra problem solving among university students. International Conference on Mathematics Education Research (ICMER). Procedia Social and Behavioral Sciences, (8) 403–410.

3. Brown, A. (1987). Metacognition, executive control, self-regulation, and other more mysterious mechanisms. In Weinert, F., and Kluwe, R. (eds.), *Metacognition, Motivation, and Understanding;* New Jersey: Erlbaum. 65-116

4. Çalişkan, M & Sünbül, A.M. (2011). The effects of learning strategies instruction on metacognitive knowledge, using metacognitive skills and academic achievement (Primary Education Sixth Grade Turkish Course Sample). *Educational Sciences: Theory & Practice*. 11(1), 148-153

5. Charles-Ogan, G (2014). Metacognitive strategy and senior secondary school mathematics students' misconceptions in Rivers State. *The Journal of Mathematical Association of Nigeria, ABACUS,* 39(1) 234-246.

6. Desoete, A. (2007). Evaluating and improving the mathematics teaching-learning process through metacognition? *Electronic Journal of Research in Educational Psychology,* 5 (3), 705-730.

7. Flavell, J.H. (1976). *Metacognitive aspects of problem-solving*. In L.B. Resnick (Ed.), The nature of intelligence(231-236). New Jersey: Erlbaum

8. Nett, U.E., Goetz,T., Hall, N.C. & Frenzel, A.C. (2012). Metacognitive strategies and test performance: An experience sampling analysis of students' learning behavior. *Education Research International*.

9. Ogunkunle R.A. (2009). Teachers' effectiveness as emergent issue confronting quality mathematics education in primary schools in Rivers State. *African Journal of Historical Sciences in Education, 5 (*1&2), 73-80.

10. Ogunkunle, R.A. & Wonu, N.(2012). Effect of metacognitive strategy on the prediction skills of students with Developmental Dyscalculia (DD) in number and numeration. *Journal of Issues in Professional Teacher Education (JIPTE), 3(3), 120-131.*

11. Özsoy, G. & Ataman, A. (2009). The effect of metacognitive strategy training on mathematical problem solving achievement. *International Electronic Journal of Elementary Education, 1(2),* 67-82.

12. Uloko, E.S, Imoko, B.I (2007). Effect of ethnomathematics teaching approach and gender on students' achievement in Locus. J. Natl. Assoc. Sci. Humanit. Educ. Res. 5(1): 31-36

13. Wonu, N (2012). Effect of metacognitive strategy on the achievement of students with developmental dyscalculia in number and numeration. An M.Ed Thesis presented to the Department of Curriculum Studies and Educational Technology. University of Port Harcourt.

14. Wonu, N& Anaekwe, E (2014). School effects on students' mathematical achievement in Obio/Akpor Local Government Area of Rivers State. *International Journal of Educational Development,4(1), 69-77.*

15. Wonu, N& Ogunkunle, R.A (2015). Effects of metacognitive strategy on the planning skills in number and numeration of students with developmental dyscalculia. *The Journal of Mathematical Association of Nigeria, ABACUS,* 40(1) 22-34.