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Constructivist class of instructional models and senior secondary student geometry achievement

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Abstract

This study was an exploration of the effects of a Constructivist Class of Instructional Models (CCoIM) on geometry achievement of senior secondary students in Abua/Odual Local Government Area (LGA) of Rivers State, Nigeria. The Teaching for Understanding (TfU) and Metacognitive Instructional (MCI) models were used. The quasi-experimental design was adopted. A total of 43 SSSI students with an average age of 16 years took part in the study. A validated 25-item Geometry Achievement Test (GAT) was used for data collection. The reliability index, 0.81 of GAT was determined using KR-21. This study was guided by four research questions and four null hypotheses respectively. Mean and Standard Deviation (SD) were used to answer the research questions whereas Analysis of Covariance (ANCOVA) was used to test the hypotheses at. 05 alpha level. The findings among others established that the CCoIM significantly advanced the geometry achievement of students. The MCI model was proven to be more efficacious than TfU in improving the geometry achievement of the students. No significant sex difference was found over geometry achievement given the instructional models. It was recommended among others that Mathematics teachers should strive to apply the CCoIM in teaching students the concept of geometry since this study substantiates the fact that the MCI and the TfU are capable of enhancing the learning of geometry among students.

Keywords: constructivism, metacognition, teaching for understanding, geometry, achievement

Introduction

Globally, there is a paradigm shift from the teacher-centered pedagogy to the student-centered pedagogy in this 21st century. Today instructional model based on constructivism is recommended in our educational sector. The constructivist instructional approach is a teaching strategy that is rooted in constructivism and it promotes critical thinking and produces active, motivated and independent learners (Aniodoh & Eze, 2014) [1]. Constructivism is a theory of knowledge that holds that humans create knowledge and meaning from an interaction between their experiences and their ideas. It describes how learning happens, irrespective of whether the learners are using their experiences to understand a lecture or following the instructions for building a model.

Constructivism is a theory of Jean Piaget (Piaget, 1929; 1977) [11, 12] which holds that knowledge is not merely conveyed from teacher to student but actively modeled in the mind of the learner. Instructions based on the theory of constructivism have been found effective in the improvement of the performance of students and enhanced their motivation to learn (Hagen, 2000; Paino, 2001) [7, 13]. Duyilemi and Bolajoko, (2014) [4] studied the effects of a constructivist class of instructional model on the achievement and retention in biology among senior secondary schools in Ondo State. The study proved that the learners who were taught using constructivist instructional strategy significantly performed better than their counterparts over achievement and retention. However, the male students outperformed the female students among those instructed with the constructivist model. Some examples of instructional models that are based on constructivism are Metacognition and Teaching for Understanding (TfU). These set of Constructivist Class of Instructional Models (CCoIM) were considered in this research.

Metacognition is associated with intelligence and it makes us successful learners. The concept of metacognition was first presented by John Flavell following on the concept of metamemory (Flavell 1976) [5]. Metacognition is defined as thinking about thinking or an individual's cognition about cognition (Wellman, 1985) [16]. It entails the ability of the learner to regulate his thinking process during a problem-solving task performance. The two major categories of metacognition are metacognitive regulation and metacognitive knowledge. The former entails activities that encompass conscious reflection on one's cognitive skills and activities and the later has to do with activities regarding self-regulatory mechanisms during an ongoing effort to learn or solve problems (Brown, 1987) [3]. The regulation component contains the skills that are used in problem-solving. The skills include prediction, planning, monitoring, and evaluation skills. The knowledge components include declarative knowledge, conditional knowledge, and procedural knowledge. Recent researches have proven that metacognition can advance the mathematical achievement of students regardless of their gender. (Wonu, 2012; Ogunkunle & Wonu 2012) [9, 17].

The TfU is a pedagogical tool for designing, conducting and reflecting on classroom practices that promote student understanding. The TfU framework is built on the assumptions of the constructivist theorem (Perkins 2006) [15]. It was pioneered by Tina Blythe and associates at Harvard Graduate School of Education (Perkins & Blythe 1994) [14]. The key concept in the TfU context is student understanding. It emphasizes that the students should be able to explain what has been learned in their own language and transfer such understanding into a novel situation which shares similar characteristics with real-life situation used to commence the learning. Grouws and Cebulla (2000) [6] maintained that teaching for understanding and meaning has proven to be efficacious in advancing mathematical instructions in earlier studies. Transfer of learning to a new learning episode is extremely impacted by the level the learners studied the material with understanding instead of merely memorizing the materials or simply following a rigid set of procedures (Bransford, Brown & Cocking, 2000) [2].

Problem specification

The abysmal performance of learners in mathematics in both external and internal examinations is a recurring decimal. The scientific and technological advancement of the Nation might be an illusion if nothing is done to remediate this awful scenario. The key factor leading to this failure may be related to unsuitable earlier teaching by the mathematics teachers. Ogunkunle (2009) [8] confirmed that school teachers in Port Harcourt were not effective in mathematics teaching because they adopt the conventional strategies in nearly every topic they teach. Stakeholders in education have been making efforts to improve student mathematical achievement. It is hoped that when effective instructional strategy which is geared towards making the students independent thinkers, problem-solvers and discoverers, is utilized in the teaching mathematics, their performance will improve. The current study is, therefore, a peer into the relative effectiveness of the constructivist class of instructional models (Metacognition & Teaching for Understanding, TfU) in the improvement of senior secondary student learning achievement in geometry in Abua/Odual Local Government Area of Rivers State, Nigeria

Purpose of the study

The purpose of the study was to explore the efficacy of the Constructivist Class of Instructional Models (CCoIM) in advancing senior secondary student geometry achievement in Abua/Odual Local Government Area. The study specifically intends to:

1. Determine the relative effectiveness of the CCoIM on the geometry achievement of senior secondary students
2. Investigate the difference in the geometry achievement between senior secondary students taught using the metacognitive instructional model and those taught using the Problem-based Learning (PBL) model
3. Determine the difference in the geometry achievement between senior secondary students taught using the TfU model and those taught using the PBL model
4. Find out the effect of sex on the geometry achievement of senior secondary students given the CCoIM

Research Questions

The following research questions guided the study:

1. What is the relative effectiveness of the CCoIM on the geometry achievement of senior secondary students?
2. How might we describe the difference in the geometry achievement between senior secondary students taught using the metacognitive instructional model and those taught using the PBL model?
3. How might we describe the difference in the geometry achievement between senior secondary students taught using the TfU model and those taught using the PBL model?
4. What is the effect of sex on the geometry achievement of senior secondary students given the CCoIM?

Hypotheses

The following research null hypotheses guided the study:

H_{01}: There is no significant main effect of the CCoIM on the geometry achievement of senior secondary students

H_{02}: There is no significant difference in the geometry achievement between senior secondary students taught using the metacognitive instructional model and those taught using the PBL model

H_{03}: There is no significant main effect of the TfU model on the geometry achievement of senior secondary students

H_{04}: There is no significant difference in the geometry achievement between the male and the female senior secondary students given the CCoIM

Methods and Materials

Research Design

The study adopted the pre-test, post-test quasi-experimental design. Pre-test and post-test measurements and three groups were used. The purpose is to establish the relative effectiveness of the independent variable (i.e. pedagogical strategy) in advancing student geometry achievement (dependent variable).

Participants

A total of 43 SSSI students took part in the study. There were 13 (7 males & 6 females) students in the experimental group-1, 14 (7 males & 7 females) students in the experimental group-2 and 16 students (8 male & 8 females) in the control group. The average age of the participants was 16 years. Purposive sampling technique was used to select ABOLGA. Three public senior secondary schools were purposively selected for participation in the study. Simple random sampling technique was then used to select an arm of SSSI class in each of the school. Two arms of the classes were assigned to experimental groups in two different schools selected. Then an arm was assigned to the control group in the remaining school.

Instrumentation

Geometry Achievement Test (GAT) was used for data collection. The GAT is a quantitative measure of student geometry achievement. The instrument consisted of 25 items with multiple choice options marked over 100. The reliability of GAT was established using the KR-21 reliability method to obtain an index of 0.81. The pre-GAT was administered to all groups and the test scripts collected before the beginning of the lesson by the instructor.

Treatments

Before the commencement of instruction in all groups, students were made to attempt the 25 questions on GAT which served as the pre-test. Then, the students in experimental group-1were instructed geometry with the MCI model while those in experimental group-2 were taught the same topic using the TfU model. The usual mathematics teacher in each selected school was used to implement the teaching which lasted for 3 weeks. The teachers were given training on the practical and theoretical aspect of the instruction.

Intervention Group-1

A large class, small groups, and individual activities were used in this group. To inspire the advancing of problem-solving skills using metacognition, the students in this group were taught with the aid of the metacognitive work-sheets. The worksheets were used to direct the activities of the students through some self/teacher directed questions found on it. The prediction, planning, monitoring and evaluation skills of metacognition were used. They forecasted the difficulties of tasks before solving them, planned in advance the way to obtain the solution. The students monitored their engagement in the actual problem-solving process and appraised the outcome regulatory process of their learning. The role of the teacher during this period was asking probing questions that ignite critical thinking skills among learners and make the process proceed smoothly.

Intervention Group-2

The experimental group-2 was taught with the TfU model. The instructions were centered around the TfU framework. The instructions in this group were directed using TfU worksheet during the actual implementation of the model. The TfU framework utilized was tailored after Perkins and Blythe (1994) [15], The activities in this group were done individually, large class and in small groups.

Control Group

The strategy adopted in this group was Problem-Based Learning. It has some essential phases: Problem STUDY, solution Process PLANNING, Solution plan EXECUTION, Solution outcome EVALUATION, and Problem mastery DEVELOPMENT. The utilization of this model for instruction requires the instructor to ignite the passion of the class towards classwork using the Polya phases considering the specific problem being solved.

Data Analysis

The Pre-GAT and Post-GAT scores of the participants were used. Mean and Standard Deviation (SD) were used to answer the research questions whereas the Analysis of Covariance (ANCOVA) was used to test the hypotheses at the. 05 alpha level.

Results

Table 1: Pre-GAT, Post-GAT and learning gain of students using the CCoIM

		Pre-GAT		Post- GAT		Gain		95% CI	
Model	**N**	$\bar{X}$	**SD**	$\bar{X}$	**SD**	$\bar{X}$	**SD**	**LB**	**UB**
MCI	13	19.69	14.83	48.31	14.46	28.62	14.86	19.63	37.60
TfU	14	23.43	4.67	33.71	11.82	10.29	9.24	4.95	15.62
PBL	16	25.50	11.67	33.25	11.38	7.75	9.29	2.80	12.70

Key: LB=Lower Bound (for gain scores), UB=Upper Bound (for gain scores), SD=Standard Deviation, CI=95% Confidence Interval, N= Number of participants in each group

The result shown in Table 1 indicated that the mean gain of students instructed the MCI model was 28.62 $\pm$ 14.86 while their 95% CI moved from 19.63 to 37.60. The students taught using TfU had a mean gain of 10.29 $\pm$ 9.24 and with their 95% CI moved from 4.95 to 15.62 whereas the geometry mean gain of students taught using the PBL was found to be 7.75 $\pm$ 9.29 while their 95% CI moved from 2.80 to 12.70.

Table 2: Sex-related Pre-GAT, Post-GAT and learning gain of students using the CCoIM

			Pre-GAT		Post-GAT		Gain		95% CI	
Model	**Sex**	**N**	$\bar{X}$	**SD**	$\bar{X}$	**SD**	$\bar{X}$	**SD**	**LB**	**UB**
MCI	Male	7	21.71	15.29	45.71	15.47	24.00	11.55	13.32	34.68
	Female	6	17.33	15.32	51.33	13.95	34.00	17.48	15.65	52.35
TFU	Male	7	22.86	5.52	33.14	9.72	10.29	6.47	4.30	16.27
	Female	7	24.00	4.00	34.29	14.40	10.29	11.97	-0.78	21.35
PBL	Male	8	24.50	11.80	31.00	11.86	6.50	7.98	-0.17	13.17
	Female	8	26.50	12.27	35.50	11.20	9.00	10.85	-0.07	18.07

The result as shown in Table 2 indicated that the mean learning gain in geometry for male students taught using MCI Model was 24.00 $\pm$ 11.55 while their 95% CI moved from 13.32 to 34.68. The male students taught geometry using the TfU model had mean learning gain of 10.29 $\pm$ 6.47 while their 95% CI moved from 4.30 to 16.27. The male students instructed with the PBL model had a mean gain of 6.50 $\pm$ 7.98 while the 95% CI moved from -0.17 to 13.17. The result from Table 2 indicated that the female students instructed with the MCI model had a mean gain of 34.00 $\pm$ 17.48 while their 95% CI moved from 15.65 to 52.35. The female students instructed with the TfU model had a mean gain of 10.29 $\pm$ 11.97 while the 95% CI moved from -0.78to 21.35. The female students instructed with the PBL model had a mean gain of 9.00 $\pm$ 10.85 while their 95% CI moved from -0.07 to 18.07.

Table 3: Summary of ANCOVA on the main effect of CCoIM on the geometry achievement of senior secondary students in Abua/Adual LGA

Source	SS	df	MS	F	Sig.	η^2
Pre-GAT	1921.305	1	1921.305	17.236	.000	.306
Treatment	2787.249	2	1393.625	12.502	.000	.391
Error	4347.321	39	111.470			
Total	70208.000	43				
Corrected Total	8267.907	42				

Key: SS=Type III Sum of Squares, df=Degree of freedom, MS=Mean Square
η^2=Partial eta squared for Cohen effect size

Table 3 shows the summary of ANCOVA on the main effect of CCoIM on the geometry achievement of senior secondary students. It was found that there was a significant main effect of a constructivist class of instructional models on the geometry achievement of senior secondary students (F2, 39=12.502, p=.000, η^2=0.391). This led credence to the rejection of the null hypothesis one at the. 05 alpha level.

Table 4: Summary of ANCOVA on the relative main effects of the MCI and the TfU models on the geometry achievement of senior secondary students in Abua/Adual LGA

Source	SS	df	MS	F	Sig.	η^2
MCI	2278.079	1	2278.079	19.642	.000	.430
TfU	32.532	1	32.532	.381	.542	.014

The result presented in Table 4 shows that there was a significant main effect of the metacognitive instructional model on the geometry achievement of senior secondary students (F=19.64, p=.000, η^2=0.43). This result led credence to the rejection of null hypothesis two at. 05 alpha level. Table 4 also shows that there was no significant main effect of TfU model on the geometry achievement of senior secondary students (F=.381, p=.542, η^2=0.14). The null hypothesis three was not rejected at. 05 alpha level

Table 5: Summary of ANCOVA on the simple main effect of sex on the geometry achievement of senior secondary students in Abua/Adual LGA

Independent variables	SS	df	MS	F	Sig.	η^2
Male	1152.082	2	576.041	7.485	.004	.454
Female	1565.738	2	782.869	5.177	.018	.379
MCI	195.808	1	195.808	1.136	.312	.102
TFU	2.558	1	2.558	.030	.867	.003
PBL	40.845	1	40.845	.523	.482	.039

Table 5 shows that the students of both sexes instructed with the MCI model (F=1.136, p=. 312, η^2=.102), TfU model (F=.030, p=.867, η^2=.003) and PBL (F=.523, p=.482, η^2=.039) respectively had no significant difference over geometry achievement. This led credence to the rejection of hypothesis four at. 05 alpha level. Table 5 further indicated that different groups of male students instructed using the three instructional models differed significantly in terms of geometry achievement (F=7.485, p=.004, η^2=.454). The different groups of female students instructed using the three instructional models also differed significantly in terms of geometry achievement (F=5.177, p=.018, η^2=.379).

Discussion

Constructivist class of instructional models and student geometry achievement

The students taught using the CCoIM outgained those taught using the PBL model as shown in Table 1. The present result proved that the students instructed with the MCI model had the highest mean gain among others. In more specific terms, the students instructed with the MCI model and those instructed with the TfU model outgained those taught using the PBL model with mean gains of 20.87 and 2.54 respectively. Hagen, (2000) [7] established that the constructivist instructional model is capable of leading students to successful learning and enhanced performance. The result from Table 3 shows that there was a significant main effect of a constructivist class of instructional models on the geometry achievement of senior secondary students (F2, 39=12.502, p=.000, η^2=0.391). The null hypothesis one was rejected at. 05 alpha level. A further analysis of the data as evident in Table 5 further established that different groups of male students taught using the three instructional models differed significantly in terms of achievement in geometry (F=7.485, p=.004, η^2=.454). The different groups of female students taught using the three instructional models differed significantly in terms of achievement in geometry (F=5.177, p=.018, η^2=.379). This established that the students taught using the different constructivist instructional models significantly improved in terms of learning achievement irrespective of their sex. This finding is in agreement with an earlier finding by Duyilemi and Bolajoko, (2014) [4] which proved that the students instructed with the constructivist instructional model significantly performed better than their counterparts in terms of achievement and retention in biology.

Metacognitive instructional model and student geometry achievement

The result as reflected in Table 1 indicated that the Post-GAT mean score of students instructed with the MCI model was 48.31 $\pm$ 14.46 while that of those taught using the PBL model was 33.25 $\pm$ 11.38. Furthermore, the GAT mean gain of those taught using the MCI model exceeded that of their counterparts taught using PBL with a mean gain of 20.87. This indicated that metacognitive instructional model was more effective than the PBL model respecting the improvement of students learning achievement in geometry. Ogunkunle & Wonu (2012) [9] established that the metacognitive strategy is capable of enhancing the achievement of students in mathematics. The result in Table 4 established that there was a significant difference in the learning achievement between senior secondary students taught using metacognitive instructional model and those taught geometry using problem-based learning model (F=19.64, p=.000, η^2=0.43). The null hypothesis two was rejected at. 05 alpha level. The findings of this study are consistent with an earlier finding by Wonu (2012) which established that students with developmental dyscalculia taught using metacognitive strategy outperformed that counterparts instructed using problem-solving in number and numeration.

Teaching for understanding model and students' learning achievement in geometry

The result as presented in Table 1 also showed that the Post-GAT mean score of students instructed using the TfU model was 33.71 $\pm$ 11.82 while that of those taught using PBL model was 33.25 $\pm$ 11.38. Also, the GAT mean gain of those taught using the TfU model was somewhat higher than that of their counterparts who were instructed with the PBL model with a mean gain of 2.54. This showed that the TfU model was fairly better than the PBL model in terms of advancement of the learning achievement of students in geometry. The observed gain in learning could be the reason Brans ford, Brown & Cocking, (2000) [2] strongly opined that transfer of learning to a new situation to solve problems is influenced by the level the students studied that materials with understanding instead of merely memorizing the sets of facts or procedures. The result in Table 4 indicated that there was no significant main effect of teaching for understanding (TfU) model on the learning achievement of senior secondary students in geometry (F=.381, p=.542, η^2=0.14). The null hypothesis three was rejected at. 05 alpha level. The findings of this study are consistent with earlier findings of Grouws and Cebulla (2000) [6] which showed that teaching for understanding and meaning has been shown to be effective in teaching and learning of mathematics in earlier studies.

Effects of sex on the geometry achievement of students given the CCoIM

The result from Table 2 indicated that the female students instructed with MCI model performed better than their counterparts instructed with TfU and the PBL in terms of geometry achievement respectively. Specifically, the female students taught using the MCI model benefited more than the female students instructed with TfU and the PBL models with mean gains of 23.71 and 25.00 respectively. The female students instructed with the TfU model also gained more than the female students instructed using the PBL with a mean gain of 1.29. Similarly, the male students instructed using MCI model gained more than the male students instructed with the TfU and the PBL models with mean gains of 13.71 and 17.50 respectively. The male students who were instructed with the TfU model also gained more than the male students instructed with the PBL model with a mean gain of 3.79. When put to statistical test, the result in Table 5 proved that the students of both sexes instructed using the MCI model (F=1.136, p=. 312, η^2=.102), TfU model (F=.030, p=.867, η^2=.003) and PBL (F=.523, p=.482, η^2=.039) respectively did not differ significantly in terms of geometry achievement. The findings of this study are inconsistent with an earlier finding of Duyilemi and Bolajoko, (2014) [4] which established that the male students performed better the female students among those taught using the constructivist model. The present finding is in agreement with a previous study by Okoronka and Bitrus (2014) [10] which indicated that the sex of the students had no significant main effect on their physics achievement

Conclusions

In line with the findings of the present study the following conclusions were drawn:

1. The CCoIM significantly impacted on the geometry achievement of senior secondary students in Abua/Odual LGA.
2. Both the MCI and the TfU models respectively enhanced student geometry achievement. However, the TFU model was almost as effective as the PBL model in the improvement of students learning achievement in geometry.
3. The students of both sexes instructed with the MCI model benefited most from the experiment. However, no significant effect of sex on the learning achievement of students in geometry

Recommendations

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

1. Mathematics teachers should strive to apply the CCoIM in teaching students the concept of geometry since this study substantiates the fact that the MCI and the TfU are capable of enhancing the learning of geometry among students
2. Teachers should involve students of both sexes in mathematics problem-solving to develop their Higher Order Mathematics Skills (HOMS) of problem formulation, problem analysis and problem-solving. This will aid to minimize the gender inequity in mathematics achievement in Nigeria
3. Stakeholders in education should try to organize seminars and workshops to equip teachers with the latest skills needed to function effectively in the delivery of instructions using innovative instructional models such as the MCI and the TfU models in the 21st century.

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