



## Advancing Student Solid Geometry Achievement through Constructivist-based Instructional Models

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### Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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## Abstract

This study investigated the applicability of a class of instructional models based on constructivism in improving the achievement of senior secondary students in solid geometry using the quasi-experimental design. Two constructivist-based instructional models used were Teaching for Understanding (TfU) and Metacognitive Instructional (MCI) models. The exploration area was the Emohua Local Government Area (LGA) of Rivers State, Nigeria. An aggregate of 86 Senior Secondary Class I (SSC1) students took an interest in the investigation. To evaluate the achievement of the students in solid geometry, the researchers structured, approved and utilised an achievement test in solid geometry which contained 50 multiple-choice questions. The reliability of the test was determined using KR-21 to get an index of 0.84. This research work was guided by two research questions and two null hypotheses separately. The mean, standard deviation, box-plots and Analysis of Covariance (ANCOVA) were used for data analysis. The findings showed that the class of instructional models based on constructivism significantly enhanced the learning of solid geometry amongst the SSC1 students. The MCI model was less effective than the TfU model in improving the learning of the students. Sex had no significant influence on the solid geometry achievement of SSC1 students irrespective of the instructional model used. The exploration suggested among others that solid geometry ought to be instructed by the educators of arithmetic using the instructional models based on constructivism.

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## **1 Introduction**

Constructivism has its roots in the 18th-century philosophies of Immanuel Kant and Giambattista Vico, although some have traced it as far back as the 4th century B.C. [1,2]. Constructivism is a philosophy of learning founded on the premise that by reflecting on our experiences we construct our own understanding of the world we live in. Constructivism states that all knowledge is constructed from a base of prior knowledge. Children learn best when they are allowed to construct a personal understanding based on experiencing things and reflecting on those experiences. It holds that meanings and knowledge can be constructed by people through experiences. The theory was spearheaded by Jean Piaget [3,4] and it posits that there is a construction of knowledge in the mind of the student, so knowledge is not simply passed on from the instructor to the student. A recent study by Mays [5] reviewed that the theoretical establishments of constructivism's cutting edge origination emerged from late nineteenth - and early twentieth-century advances in early childhood training and intellectual improvement [6] and underscore students' internal universe of subjective and perceptual advancement [3], deliberate hands-on learning exercises [7] and the significance of environment and social connection to learning and development [8,9,10].

The TfU and the MCI models are anchored on the constructivist theory of instruction. Many studies have been carried out to find out the efficacies of instructions based on constructivism in advancing student learning outcomes [2,7,9,11,12,13,14,15]. The set of instructional models based on constructivism creates a stimulating setting for the students and advances their mastery of Mathematics. The capacity of students to self-regulate their thinking process and control their mathematical concepts and reflect critically tends to be achieved when learners study to build personal understanding. The achievement of this goal is certain because the constructivist-based instructional models inspire the utilisation of teaching aids [16,17,18].

### **1.1 Constructivism and active learning models**

Constructivism is a learning theory that portrays the procedure of knowledge construction. Knowledge construction is certifiably not an uninvolved procedure, yet an active process. Constructivists accept that information ought to be built by the students themselves through active involvement in the learning procedure instead of having the targeted content deposited in the students' minds [19]. Most of the constructivist-based instructional models are active learning models. Watkins, Carnell, and Lodge [20] demonstrated that an active learning model can be viewed as a reflective cycle that empowers students to assess a performed action and reformulate their tactics dependent on the result of that activity. The segments of the reflective cycle incorporate the plan, do, review, learn and apply. This demonstrates that the result or substance of learning with active learning is the performance of understanding which is an application of learning. The construction of all new knowledge depends on earlier information (experiences).

In the United States of America, Mays [5] worked on the identification of the vital components of constructivism and constructionism which have been confirmed to advance the affective and intellectual development of learners and to adopt these components to career teaching in tertiary (postsecondary) education settings. The study successfully identified these components applicable to workforce development in a tertiary education setting in the study area through a systematic exploration of existing theory and study related to human capital, constructionism and constructivism. The study further maintained that the overarching goal of adopting these two strategies was to endow learners in the tertiary institutions to internalize the knowledge gained from their career field and for its real-world applications along with reinforcing the learners' analytical skills, ethics, perseverance, creativity, and behavioural workplace competencies. Seven essential components of constructivism and constructionism were extracted to accomplish the goal. These components included: the entire individual, the structure of knowledge, cleverly equipped learning settings, the teacher as a subtle facilitator and an expert guide, pragmatic learning, social interaction, collaborative learning and reflection. Since constructivism is based on reflection and transfer of learned information to the new circumstance or situation, the two treatment groups of students receiving the MCI and the TfU models will be made to engage in activities that could upgrade their adaptability in critical

thinking, problem-solving and application of knowledge in a novel circumstance. The two explored constructivist-based instructional models are active learning models.

## **1.2 Constructivist-based instructional models and student learning achievement**

An exploration of the effects of active learning methods on achievement, attitudes toward instructional measurement and evaluation courses and perceptions about the entire learning process among pre-service teachers was carried out by Oguz [21]. The study used the pretest, posttest experimental design with a qualitative research method. The findings established that the experimental group significantly outperformed the control group over attitudes and student learning achievement levels. This study proved that the constructivist-based instructional models advanced student perception and enhanced their success in learning. Similarly, Tok [22] explored the effects of the Know-Want-Learn (KWL) strategy on the mathematical achievement, metacognitive skill, and Mathematics anxiety of students in grade 6. The study established that the KWL model was more efficacious than the traditional strategy in advancing students' achievement and metacognition. However, KWL was not more effective than the conventional strategy over anxiety reduction. Wonu and Paul-Worika [15] explored the efficacy of metacognitive instructional strategy in advancing the knowledge of cognition of junior secondary students with Mathematics Disability (MD) in Port Harcourt Nigeria. The quasi-experimental design was adopted. The findings established that the experimental group taught using metacognitive instructional strategy significantly outperformed their counterparts in the control group in terms of conditional, declarative and procedural knowledge respectively.

Awofala, [23] studied the effect of concept mapping on the academic achievement of JSC3 students in Nigeria. The study established that concept mapping was effective for instruction in Mathematics. The strategy had the capability of enhancing students' mastery of content at higher-order levels of cognition. The Mathematics teacher level of utilisation of the constructivist instructional model in teaching Mathematics was explored in Botswana by Major and Mangope [19]. The study was of a comparative type. The investigation set up that a straightforward review of rules was expected of the students in the bigger level of the watched exercises while the investigation of the connection between thoughts was expected of students in an extremely little level of the watched exercises. Another exploration by Kalogiannakis and Papadakis [24] also utilised the Technology Acceptance Model to look at the degree to which the ICT skills of pre-service teachers and their attitude toward the utilization of cell phones influence their readiness to utilise advanced mobile phones gadgets in teaching natural sciences at the kindergarten level. The findings were that pre-service teachers' attitudes toward the usefulness of mobile learning in the instructional process had the most significant impact on intention to adopt mobile learning followed by perceived ease of use. Zalmon, Wonu, and Chikwem [18] explored the impacts of teacher utilization of selected instructional strategies on the Algebra achievement of senior secondary students in Rivers State, Nigeria. The study adopted the correlational research design. The findings showed that the teachers had knowledge of the innovative instructional strategies, specifically in terms of team teaching and mastery learning. Classroom delivery was one of the reasons they utilized innovative instructional strategies. The result further established that the mostly utilised innovative instructional strategies were vee mapping and inquiry learning. The joint contribution of teacher knowledge and utilization of the innovative instructional strategies to the achievement of the senior secondary students in Algebra was statistically significant.

## **1.3 Constructivist-based instructional models and gender-associated student achievement**

Duyilemi and Bolajoko, [25] explored the efficacy of the constructivists' instructional model in an attempt to advance the biology learning achievement and retention of students. The quasi-experimental group was adopted. The findings demonstrated that the students in the treatment group significantly outperformed their partners in the benchmark group on biology achievement and retention. The male students who took part in the treatment group outperformed their counterparts in the control group. A study in Nigeria combined some tenets of constructivism to instill knowledge among learners. Concept mapping, cognitive apprenticeship, and cooperative work skills were the assessed elements of constructivism [26]. The findings uncovered that

the students who were trained using the instructional models based on constructivism essentially beat their partners who were taught with the conventional strategy. There were no significant differences in the variables measured based on sex.

The relative effects of analogy learning model, gender and cognitive style on the Physics learning achievement of students in Mubi Metropolis, Nigeria was explored by Okoronka and Bitrus [27]. A pretest, posttest, non-randomised control group, quasi-experimental design was used. The findings established that the experimental group did better than the control group over achievement in Physics. The interaction of gender and cognitive style was statistically significant in terms of student achievement in Physics. There was no significant difference between the male and female students over Physics achievement in the post Physics achievement test scores. In comparative research work, the impact of instructional simulation on the biology achievement of students was investigated by Umoke and Nwafor [28]. The outcome indicated that instructional simulation was more compelling than the conventional strategy in the advancement of biology achievement. There was no significant difference in the biology achievement between the male and the female students taught using the simulated model. There was no significant interaction of treatment and sex over student learning achievement in biology. Dorji, Panjaburee and Srisawasdi [29] focused on the exploration of the main effect of Residential Energy Saving battle (RES-battle) on student learning achievement and awareness of energy-saving in physics. The findings established that the RES-battle was efficacious in practically minimizing the awareness and learning achievement gap in energy-saving across student gender.

Papadakis, Kalogiannakis, and Zaranis [30] investigated and compared the influence of teaching Realistic Mathematics on the acquisition of mathematical competence in kindergarten. The findings established that instructions based on Realistic Mathematics Education contributed significantly to the development of mathematics competence of kindergarten. Furthermore, age, gender, and nonverbal cognitive ability had no significant influence on the acquisition of Mathematics competence among young children. Papadakis [31] evaluated pre-service teachers' acceptance of mobile devices with regard to their age and gender. This study was conducted in Greece. The framework for analysis used was the Technology Acceptance Model with some additional constructs. The purpose of the study was to assess the background variables of the teachers, including gender and age, in an attempt to find out the extent to which they influence the use of mobile devices in class. The findings among others established that pre-service teachers had positive perceptions about mobile phones. Gender and age respectively had no significant influence on the purpose of using smart mobile devices. Another study by Papadakis, Kalogiannakis, and Zaranis [32] explored and compared the influence of tablets and computers in the improvement of mathematical competence of learners at the early childhood education level. An experimental design was adopted. The findings showed that instructions using tablets in comparison with instructions using computers contributed significantly to the acquisition of mathematical ability among children. Furthermore, age and gender did not appear to distinguish the children's acquisition of mathematical competence. A similar and more recent study by Papadakis, Kalogiannakis and Zaranis, [14] assessed the effect of two different digital technologies, specifically; tablets and computers on the understanding of numbers among children in early childhood centres. The findings among others were that the two experimental groups, those that use computers and the group that use tablets significantly outperformed the control group over posttest scores; the experimental group that utilised tablets significantly performed better than the group that used computers on the posttest and gender of the children had no significant influence on their posttest.

Wonu and Ojimba [12] explored the efficacy of Systems Analysis Strategy (SAS) in advancing the Mathematics achievement of senior secondary students in Obio/Akpor Local Government Area of Rivers State, Nigeria. The quasi-experimental design was used. The findings among others were that the students in the experimental group taught using SAS significantly outperformed their counterparts in the control group over Mathematics achievement. Gender and the interaction of treatment and gender had no significant influence on the Mathematics Achievement of the learners. Wonu and Harrison [13] investigated the effects of a constructivist class of instructional models on the geometry achievement of senior secondary students in Abua/Odua Local Government Area of Rivers State, Nigeria. The findings among others showed that instructions based on the tenets of metacognition which is anchored on constructivism successfully improved

the learning achievement of the students in geometry more than TfU model. There was no significant influence of gender on the geometry achievement of the students given the teaching methods.

#### **1.4 Problem specification**

It is undeniable that student underachievement in annual national examinations is an overarching problem to the Mathematics educators. Mathematics teacher proficiency in the application of teaching methods based on the theory of constructivism in an effort to advance the achievement of students in Mathematics in Emohua LGA is uncertain. This situation could be linked with the outcome of a study by Ogunkunle [33] that disclosed the ineffectiveness of teachers in the delivery of Mathematics instructions in the schools in Port Harcourt. The effect of a class of instructional models based on constructivism on the geometry achievement of students has been explored in a previous study [13]. Wonu and Charles-Ogan [34,35] also explored the relative efficacies of distinct constructivist instructional models in improving the solid geometry achievement of students separately. These studies did not explore the impact of the two selected constructivist-based instructional models in advancing the learning achievement of the students in solid geometry. Nevertheless, there appears to be limited literature on the use of the targeted class of teaching models based on constructivism in enhancing the Solid Geometry Achievement (SGLA) of the SSC1 students in the proposed study area. This exploration attempts to investigate how well two instructional models based on constructivism respectively performed in advancing the achievement of senior secondary students in solid geometry in Emohua LGA of Rivers State when compared with PbL in a single study. It is based on this premise, this study was designed.

#### **1.5 Aim and objectives of the study**

The efficacy of a set of constructivist-based instructional models in the improvement of the achievement of the senior secondary students in solid geometry in Emohua LGA of River State was explored. Specifically, the objectives of the study are to:

1. Determine the effect of constructivist-based instructional models on the solid geometry achievement of senior secondary students.
2. Compare the difference between solid geometry achievement of the male and the female SSC1 students taught using constructivist-based instructional models over PbL

#### **1.6 Research questions**

The following research questions guided the study:

1. What is the effect of constructivist-based instructional models on the achievement of senior secondary students in solid geometry?
2. How might we describe the difference between the mean solid geometry achievement scores of the male and the female students taught using constructivist-based instructional models over the PbL model?

#### **Hypotheses:**

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

$H_{01}$ : There is no significant effect of the constructivist-based instructional models on the solid geometry achievement of the senior secondary students.

$H_{02}$ : The male and the female students taught using constructivist-based instructional models do not differ significantly in the mean solid geometry achievement scores over the PbL model.

## 2 Method and Materials

### 2.1 Research design

The pretest, posttest quasi-experimental design was used in the study. It was necessary to use this design because the selection of the subjects for participation in the study was not randomized to avoid disorganization of the classes in the school. Intact classes were used. The instructional models and the learning achievement of the students in solid geometry are the independent and dependent variables respectively. The researchers sought the permission of the Principals of three senior secondary schools in Emohua LGA involved in the study to carry out the study. Approval was given by each of the principals for the researchers to carry out the experiment and to collect data from the students in the schools.

### 2.2 Participants

An aggregate of 86 SSC1 students took part in the study, out of which there were 39 males and 47 females. A total of 28 students (17 male & 11 females) participated in the constructivist group taught with metacognition while another 28 students (10 males & 18 females) took part in another constructivist-based group who utilised TfU model and an aggregate of 30 students (12 males & 18 females) were in the control group trained using PbL model. The mean age of the participants was 15 years. Three senior secondary schools were selected for the exploration. Only one arm of SSC1 class per school was used. Two of the classes were randomly assigned to the experimental groups whereas one of the classes was assigned to the control group.

### 2.3 Instrumentation

Solid Geometry Achievement Test (SGAT) was used for data collection. The SGAT had 50 items, designed by the researchers and used to measure the solid geometry achievement of the students. The instrument quantified five content areas in solid geometry for SSC1 students. This included composite solids, frustum of a cone and of the pyramid, total surface area and volume of solid shapes. The SGAT was validated by the researchers who are as well experts in Mathematics education. The instrument had a reliability index of 0.84 using KR-21.

### 2.4 Research procedures

The prospective and retrospective evaluations of the students using SGAT were carried out by trained educators. The scripts from the pre-test evaluation were retrieved before initiating proper directions by the teachers. The researchers arranged and built up the exercises for the treatment and control groups. The researchers gave the teachers intensive orientation on the theoretical and the practical parts of constructivist-based instructional models for two days. Minimal instructions were given to the teacher in the control group in comparison to the training given to the teachers in the experimental groups. Before the teaching commenced in all groups, copies of SGAT were administered to all the students as a pre-test and allowed them 45 minutes to attempt the questions. The pre-test scripts of SGAT were retrieved from the students when finished. The instructions were delivered in both experimental and control groups simultaneously. Two (double) periods of 40 minutes per period/lesson (1 hour, 20 minutes) were dedicated to instructions in the experimental groups since the activities of engagement required more time for planning and execution, whereas the normal one period of 40 minutes per lesson was given to the control group. The experiment took place once per week for 5 weeks. The aim was to cover the five content areas studied: composite solids, frustum of a cone and of the pyramid, total surface area and volume of solid shapes. A posttest on SGAT was administered to all participants after treatment in all groups.

**Experimental group 1:** The steps and procedures adopted in the problem-solving phase of the MCI model were an adaptation and modification from Brown [36]. Previous studies established that metacognitive regulation of cognition consists of four vital strategies in Mathematical problem-solving, including prediction, monitoring, planning and evaluation [36,37,38]. Table 1 shows a summary of the description of the instructional activities.

**Table 1. Summarised MCI model activities**

<b>Strategic component</b>	<b>Instruction</b>	<b>Student activity</b>	<b>Type of activity</b>
<b>Prediction</b>	To teach the skill of <b>prediction</b> the students are asked by the teacher to predict if they could solve and obtain the correct answer to the problem some minutes before solving it.	This enables each student or group to forecast difficulties and relate the problem to other ones. They use the worksheet to predict their performance	Class, Group, individual
<b>Planning</b>	Ask the students how they <b>plan</b> to obtain the correct answer to the problem.	This enables each student or group to analyse the exercise, establish sub-goals and allocate relevant resources that will enable them to successfully solve the problem.	Class, Group, individual
<b>Monitoring</b>	The Mathematics teacher carefully guides the learners to <b>monitor</b> their progress to obtaining the solution to the problem.	This enables each student or group to identify the problem, modify the plan and self-test on the process used.	Class, Group, individual
<b>Evaluation</b>	The teacher explicitly reviews important information for a specific problem. The Mathematics teacher requests the students to assess themselves if they got the answer	Each student or groups try to evaluate their work to ascertain whether they got the answer	Class, Group, individual

**Table 2. The summarised Tfu model activities**

<b>Strategic components</b>	<b>Instruction</b>	<b>Student activity</b>	<b>Type of activity</b>
<b>Generative Topics:</b> Identify the core concept	The students are guided by the teacher to identify the core concept in the topic.	Guide the student or groups to identify the core concepts	Class, Group, individual
<b>Understanding Goals:</b> Identify the process, skills, ideas	The Mathematics teacher probes the students through questioning to identify what they are supposed to understand or comprehend, the way to derive the formula for application, where necessary and the excellent method for the execution of the solution to specific mathematical problems	Each student or group works comprehend the question or task and determine the law that fits the present task	Class, Group, individual
<b>Performance of Understanding</b> Apply knowledge	The teacher asks the students to find out what they derived from doing the present activity, see if they can apply their understanding in an attempt to solve a specific mathematical problem	The students apply their understanding in solving a problem at hand as well as to execute other related real-life tasks.	Class, Group, individual
<b>Ongoing Assessment:</b> Establish criteria & Provide feedback	The teacher asks the students questions to identify what criteria can help students understand the problem/task. Probe to see if their criteria for understanding are different from what has been presented...	The answers to the questions could be presented either through the worksheet or directly by the students and for the teacher's assessment	Class, Group, individual

**Table 3. The summarized PBL model activities**

<b>Strategic components</b>	<b>Instruction</b>	<b>Student activity</b>	<b>Type of activity</b>
<b>Study</b>	The teacher makes the students understand the problem, identify the needs in a mathematical task	The students listen to the Mathematics teacher while explaining the concept under consideration	Class
<b>Planning</b>	The teacher discloses the process that will give rise to the solution of the problem at hand	The students pay keen attention to the teacher as steps that could yield the solution to the mathematical task is identified. They also jot down some points.	Class
<b>Execution</b>	The Mathematics teacher solves the problem as well as explains each step used to obtain the answer/solution	The students solve the present problem while the Mathematics teacher tries to observe the actions taken by the students at every stage of the execution of the solution.	Class
<b>Evaluation</b>	This teacher assists the learners to crosscheck the procedures used to get the solution. This is done to ensure the students follow the correct steps and for understanding the procedures followed to solve the problem.	The students crosscheck the procedures utilized with the teacher to ensure no mistakes were done while solving the problem	Class
<b>Development</b>	The solution process is applied by the teacher to solve related real-life problems.	The students are guided to apply the learned procedures during the lesson to solve related practical problems found in their textbooks.	Class



**Experimental group 2:** The procedure used in the problem-solving phase of the TfU model was an adaptation and a modification from Lulee [39]. Table 2 shows a summary of the description of the instructional activities.

## 2.5 Method of data analysis

The student pre-test and post-test scores in all groups were checked and scores recorded. The manually coded scores were then moved to the Statistical Package for Social Sciences (SPSS) software package for analysis. Both pretest and post-test scores were utilised for the analysis. To obtain the learning gain in solid geometry the pretest scores were subtracted from the posttest scores in all groups. The mean and standard deviation and box plots were utilised to answer the research questions whereas Analysis of Covariance (ANCOVA) was utilised to test the hypotheses at .05 level of significance. When there is a significant difference in the pretest scores between groups, Analysis of Covariance (ANCOVA) is utilised. The ANCOVA is appropriate when the mean score on pre (test before treatment) in each group demonstrates a significant difference between groups due to non-random assignments. The Analysis of Covariance is a conversion of the original scores balanced for the impacts of the covariate. Theoretically, the new set of scores that have been adjusted turns into the data for an Analysis of Variance. This shows ANCOVA is the analysis of adjusted means and it implies that ANCOVA is regularly utilised when trying to make up for not having made a random assignment of the participants to groups [40]. That is when intact classes are used.

## 3 Results

Table 4 shows that the mean SGLG of students who were taught using MCI was 17.57, SD=5.80 and the lower and upper bounds of the 95% CI were 15.32 and 19.82 respectively. The mean SGLG of who received instructions with the TfU model had a mean score of 27.86, SD=9.60 and the lower bound of the 95% CI was 24.14 whereas the upper bound was 31.58. The mean of the gain in learning solid geometry among students who received instructions with the PbL model was 21.87, SD=10.54 and the lower and upper bounds of the 95% CI were 17.93 and 25.80 respectively.

**Table 4. The summary of student solid geometry learning gain**

	MCI(N=28)		TfU(N=28)		PbL(N=30)	
	Statistic	Std. Error	Statistic	Std. Error	Statistic	Std. Error
Mean	17.57	1.10	27.86	1.81	21.87	1.92
95% CI for Lower Bound	15.32		24.14		17.93	
Mean Upper Bound	19.82		31.58		25.80	
Median	18.00		27.00		24.00	
Variance	33.59		92.13		111.15	
Std. Deviation	5.80		9.60		10.54	
Minimum	8.00		14.00		-2.00	
Maximum	32.00		52.00		40.00	

\*SGLG=Solid Geometry Learning Gain (SGLG), CI= Confidence Interval for Mean

Fig. 1 shows the clustered box plots of SGLG based on treatments. Fig. 1 showed the presence of outliers. The lower 50% of the gain in solid geometry achievement of the students instructed using the MCI model ranged between 8.00 and 18.00 whereas the upper 50% ranged between 18.00 and 32.00. The lower 50% of the gain in learning among students taught using one of the constructivist instructional models, TfU ranged was flanked by 14.00 and 27.00 although the upper 50% ranged amid 27.00 and 52.00. The lower 50% of the gain in learning solid geometry amongst the students taught with the PbL model ranged between -2.00 and 24.00 whereas the upper 50% ranged between 24.00 and 40.00.

The outcome from Table 5 indicated that the mean learning gain score of the male students who were instructed with metacognition was 18.12, SD=6.28 (95% CI of LB=14.90 and UB=21.34) while the mean

learning gain score of the female student in the using the same model was 16.73, SD=5.16 (95% CI, of LB=13.26 and UB=20.19). The mean learning gain score of male students trained using the TfU model was 27.60, SD=8.32 (95% CI of LB=21.65 and UB=33.55) while the mean increase in learning of the female students in the same group was 28.00, SD=10.47(95% CI of LB=22.79 and UB=33.21). The mean gain in learning of the male students taught using the PbL model was 18.83, SD=12.69(95% CI of LB=10.77 and UB=26.90). The female students who were trained using the PbL model likewise picked up in learning with a mean score of 23.89, SD=8.64, the lower and upper bound of the 95% CI were 19.59 and 28.18 separately.

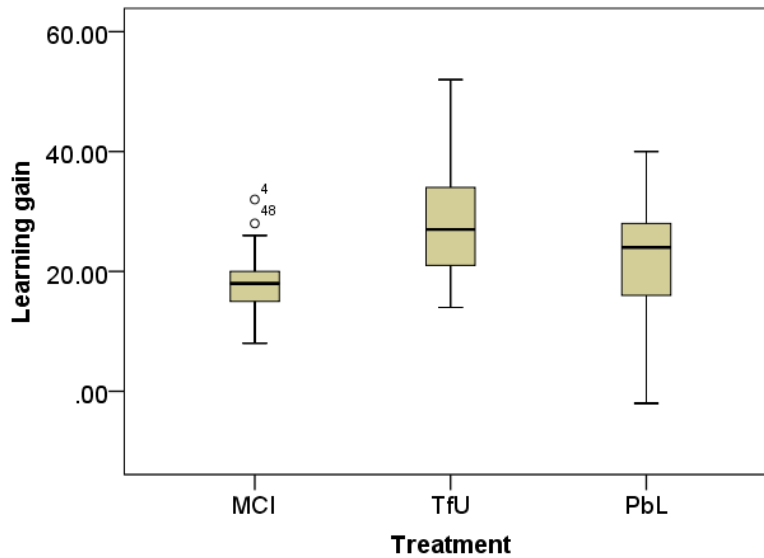


Fig. 1. Box plot

Table 5. Summary of mean SGLG based on instructional models and sex

			MCI		TfU		PbL	
			Statistic	Std. Error	Statistic	Std. Error	Statistic	Std. Error
Male	Mean		18.12	1.52	27.60	2.63	18.83	3.66
	95% CI for	Lower Bound(LB)	14.90		21.65		10.77	
		Upper Bound(UB)	21.34		33.55		26.90	
	Median		18.00		29.00		22.00	
	Std. Deviation		6.26		8.32		12.69	
	Minimum		8.00		14.00		-2.00	
	Maximum		32.00		40.00		38.00	
Female	Mean		16.73	1.56	28.00	2.47	23.89	2.04
	95% CI for	Lower Bound(LB)	13.26		22.79		19.59	
		Upper Bound(UB)	20.19		33.21		28.18	
	Median		16.00		25.00		25.00	
	Std. Deviation		5.16		10.47		8.64	

Fig. 2 shows the clustered boxplot of SGLG of students associated with instructional models and sex. There were some outliers in the lower and 50% of the learning gain scores of the students taught using metacognition based on sex. The lower half of the SGLG of male students taught with the MCI model ran somewhere in the range of 8.00 and 18.00 while the upper half went somewhere in the range of 18.00 and 32.00. The lower half of the SGLG of the female students likewise taught with the MCI model extended somewhere in the range of 8.00 and 16.00 through the upper half went somewhere in the range of 16.00 and

28.00. The lower half of the SGLG of the male students trained with the TfU model went somewhere in the range of 14.00 and 29.00 while the upper half extended somewhere in the range of 29.00 and 40.00. The lower half of the SGLG of the female students trained with the TfU model moved somewhere in the range of 14.00 and 25.00 through the upper half moved somewhere in the range of 25.00 and 52.00. The lower half of the SGLG among male students who were taught with the PbL model ran between - 2.00 and 22.00 through the upper half moved somewhere in the range of 22.00 and 38.00 while the lower half of the SGLG of the female studies trained with the PbL model ran somewhere in the range of 4.00 and 25.00 while the upper half extended somewhere in the range of 25.00 and 40.00.

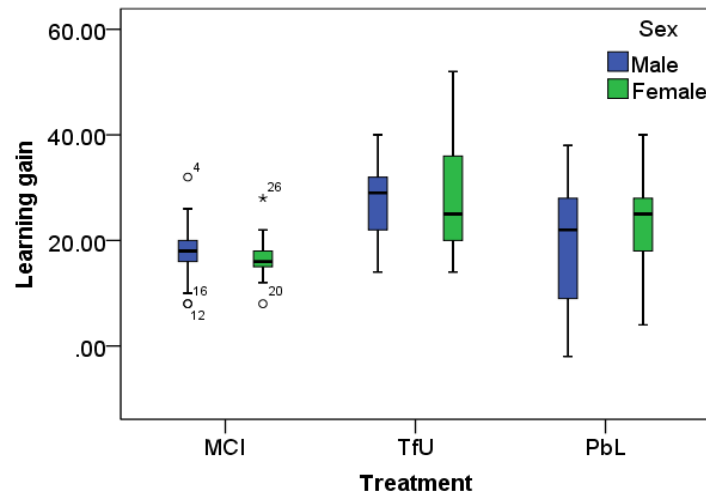


Fig. 2. Clustered boxplot based on sex and treatment

Table 6. Summary of ANCOVA results based on sex and treatment

Source	Type III Sum of squares	df	Mean Square	F	Sig.	Partial Eta Squared $\eta^2$
Pre-SGAT	9.906	1	9.906	.214	.645	.003
Treatment	552.256	2	276.128	5.973	.004	.129
Sex	20.679	1	20.679	.447	.506	.005
Error	3744.612	81	46.230			
Total	236472.000	86				
Corrected Total	4343.814	85				

Table 6 demonstrated that there was a significant main effect of constructivist-based instructional models on the solid geometry learning achievement of SSC1 students ( $F_{2, 81}=5.973, p=.004, \eta^2=.129$ ). This outcome drove belief to the rejection of the hypothesis one at .05 alpha level. The result also showed that there was no significant difference between the mean SGLA scores of the male and the female SSC1 students trained with the constructivist-based teaching models over the PbL model ( $F_{1, 81}=.447, p=.506, \eta^2=.005$ ). Hypothesis two was upheld at .05 alpha level.

## 4 Discussion of Findings

### 4.1 Constructivism and SGLA of SSC1 senior secondary students

The TfU model was found to be most beneficial in advancing the SGLA of the students. The TfU model was seen as generally gainful in propelling the SGLA of the students. The mean SGLG of students trained with

the TfU model contrasted from that of students educated with metacognition and the PbL models with 10.29 and 5.99 exclusively, (Table 4). A closer peek at Table 4 shows that some students did not gain from the instructions using the PbL model, (minimum loss score was -2.00). However, the students taught using metacognition had no loss in learning (Minimum gain score was 8.00). There were tremendous improvements in the learning gains of the students, such that students taught using metacognition recorded maximum gain a score of 32.00 whereas those taught using TfU model had a maximum gain score of 52.00 and PbL had a maximum gain score of 40.00. The results from Figure 1 showed that the upper 50% of the gain in learning among students taught using TfU ranged amid 27.00 and 52.00 whereas that of those taught using metacognition ranged between 18.00 and 32.00. The result from Table 6 indicated that there was a significant effect of the constructivist-based instructional models on the SGLA of SSC1 students. The hypothesis one was rejected at .05 level of significance. The finding is consistent with an earlier study by Wonu and Harrison [13] who investigated the effects of a constructivist class of instructional models on the geometry achievement of senior secondary students in Abua/Odua Local Government Area of Rivers State, Nigeria. The findings among others showed that instructions based on the tenets of metacognition which is anchored on constructivism successfully improved the learning achievement of the students in geometry more than TfU model. Similarly, Oguz [21] found measurably significant effects of treatment on the learning achievement levels of the students, though no significant impact of the treatment with respect to attitude. Additionally, the study found that the implemented instructional models enhanced the perception of students and improved their learning success. Similarly, Tok [22] studied the effect of the Know-Want-Learn (KWL) strategy on the mathematical achievement of metacognitive skills and Mathematics anxiety of students. The learners taught with the KWL model advanced in Mathematics learning achievement and metacognition more than their counterparts while the learners instructed using the KWL model and those instructed with the conventional method did not vary in terms of anxiety reduction. A study by Peter, Abiodun, and Jonathan [26] also established that the constructivist instructional model had a significant impact on the academic achievement of students. Studies on the effects of the constructivist instructional models on learning outcomes of students in Mathematics [12, 23, 19, 34, 35] and Biology [25, 28] have been done. Specifically, Wonu and Charles-Ogan [34, 35] have separately explored the relative impacts of TfU and Metacognition in advancing the student solid geometry achievement separately. This exploration extends the previous studies by investigating how well both constructivist-based instructional models respectively performed in advancing the learning achievement of the students in solid geometry when compared with PbL in a single study.

## 4.2 Constructivism and sex-associated SGLA of senior secondary students

The result from Table 5 showed that the male students who got trained with the TfU model had more SGLG than their male partners trained with the metacognition and the PbL models with mean SGLG scores of 9.64 and 8.93 separately. A comparable result was acquired for the female students who got trained with TfU model and had more SGLG than their female partners trained with the metacognition and the PbL models with gain scores of 11.27 and 4.11 separately. There were no significant differences between the SGLG scores of male and female students taught with the three distinctive instructional models. The result from Figure 2 showed that the lower half of the SGLG of the male students trained with the TfU model moved somewhere in the range of 14.00 and 29.00 while the upper half extended somewhere in the range of 29.00 and 40.00. The lower half of the SGLG of the female students trained with the TfU model moved somewhere in the range of 14.00 and 25.00 through the upper half moved somewhere in the range of 25.00 and 52.00. This established that the experiment was most beneficial to the female students taught using TfU model. When suggested to the statistical test (Table 6) the outcome demonstrated no significant difference between the mean SGLA scores of the male and the female SSC1 students trained with the instructions based on constructivism over the PbL model. Hypothesis two was upheld at .05 level of significance. This discovery is in agreement with prior discoveries of Peter *et al.* [26] there was no significant difference in the learning outcomes of students in the treatment group based on sex. Wonu and Harrison [13] also found no significant influence of gender on the geometry achievement of the students given the teaching methods. Another study by Papadakis, Kalogiannakis and Zaranis [30] explored and compared the influence of tablets and computers in the improvement of mathematical competence of learners at the early childhood education level. The findings showed that instructions using tablets in comparison with instructions using computers

contributed significantly to the acquisition of mathematical ability among children. Furthermore, age and gender did not appear to distinguish the children's acquisition of mathematical competence. A similar and more recent study by Papadakis, Kalogiannakis and Zaranis, [14] assessed the effect of two different digital technologies, specifically; tablets and computers on the understanding of numbers among children in early childhood centres. The findings among others were that the two experimental groups, those that use computers and the group that use tablets significantly outperformed the control group over posttest scores; the experimental group that utilised tablets significantly performed better than the group that used computers on the posttest and gender of the children had no significant influence on their posttest. Some other studies also found no significant difference in student learning outcomes based on gender [14, 25, 26, 27, 28, 29, 31].

## 5 Conclusion

This investigation has demonstrated that the constructivist-based instructional models were useful in the improvement of the SGLA of the SSC1 students. Be that as it may, the most elevated level of learning gain was found among students who were instructed utilising the TfU model. The constructivist-based instructional models respectively impacted on the SGLA of the SSC1 students in Emohua LGA. The male and the female students who were trained using the TfU model outperformed their partners trained with the MCI and PbL models respectively. The study, however, seemed to have been most beneficial to the female students who were taught using TfU model. Nonetheless, there was no significant difference between the respective mean SGLA scores of the male and the female SSC1 students instructed using the constructivist-based instructional models over the PbL model. The implication of the findings of this study is that instructions using these constructivist instructional models would be beneficial in advancing the learning achievement of the students irrespective of their gender.

## 6 Recommendations

The following recommendations were made based on the findings of the study:

1. The constructivist-based teaching models should be adopted by the Mathematics teachers in the teaching of solid geometry in the senior secondary schools.
2. To increase gender equity in Mathematics achievement, students of both sexes should be engaged equally in learning Mathematics using the constructivist-based teaching models
3. State holders in Mathematics education should try to encourage the use of these innovative instructional models based on constructivism by providing the necessary instructional materials that could be used to improve instructions and advance achievement.

## Competing Interests

Authors have declared that no competing interests exist.

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