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EFFECT OF METACOGNITIVE SCAFFOLDING TEACHING STRATEGY ON SECONDARY SCHOOL PHYSICS STUDENTS' ACHIEVEMENT AND RETENTION TO THERMAL ENERGY

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Abstract

This study investigated the effect of metacognitive scaffolding teaching strategy on secondary school physics students' achievement and retention in thermal energy in Federal Capital Territory (FCT), Abuja, Nigeria. The study answered two research questions and tested two null hypotheses at 0.05 level of significance. Quasi experimental research design involving non randomized control pretest-posttest design was utilized. The study population consisted of 2699 Senior Secondary II (SSII) physics students from 54 public SSII physics students in FCT, Abuja. Multistage random sampling technique was used to select 75 SSII physics students from two SS as sample for the study. The instrument used for data collection is Thermal Energy Achievement Test (TEAT). The data collected from the instrument were analyzed using Statistical Package for Social Science (SPSS). The research questions were answered using mean and standard deviation while the null hypotheses were tested using Analysis of Covariance (ANCOVA). Findings from the analyzed data showed that students taught using metacognitive scaffolding teaching strategy performed better in their achievement scores than those students taught using conventional teaching method. Also, physics students taught using metacognitive scaffolding teaching strategy performed better in their retention scores than their counterpart in the control group. Based on these findings, it was recommended among others that physics teachers should be encouraged to teach using metacognitive scaffolding teaching strategy. Government and educational agencies, curriculum planners and developers should encourage the training of physics teachers on metacognitive scaffolding teaching during seminars, workshops and conferences.

Keywords: Effect, Metacognitive scaffolding teaching strategy, Physics, Thermal energy, Achievement, Retention.

Introduction

Technical innovation around the world is experiencing today what emanated from the principles of scientific knowledge. Scientific knowledge contains several bodies of knowledge of the natural world. These bodies of knowledge are embedded in science subjects consisting of physics, chemistry and biology. Physics as a body of science knowledge is concerned with matter and energy and the relationship between them (Okeke, Okeke & Akande, 2008). The various knowledge acquired from Physics are applied in the field of agriculture, automobile, water supply, irrigation, civil works, electrical and electronics. Many inventions emanating from these fields which require the knowledge of physics for their understanding include electric kettle, petrol engine, diesel engine, jet engine, clinical thermometer, electric bulbs, X-ray machine, camera, car, radio, computer, television, batteries, electricity, speakers and bombs. Thermal energy also called heat energy is a branch of physics that deals with thermodynamic quantities such as heat and temperature, energy transfer which are associated with matter in physics. Energy transfer is associated with conduction, convention and radiation. The application of thermodynamics is useful to mechanical heat energy and chemical compound reactions. Despite the benefits of physics to the society, student's achievement in the subject remains low. Physics students' achievement at Senior Secondary Certificate Examination (SSCE) in Nigeria has been low over the years (Saage, 2009). Statistics of students' achievement in May/June West African Senior Secondary Certificate Examination (WASSCE) Physics examination from 2010 to 2017 as presented in Table 1 showed that students' achievement in physics has been low over the years.

Table 1: Students' Achievement in May/June2010-2017 WASSCE Physics in Nigeria

Year	Total Entry	Pass Grade Levels		Fail Grade Levels	
		(A1-C6)	%	(D7-F9)	%
2010	387,380	148,599	38.36%	238,781	61.64%
2011	374,958	162,769	43.41%	212,189	56.59%
2012	386,449	190,210	49.22%	196,239	50.78%
2013	423,146	153,137	36.19%	270,009	63.81%
2014	402,228	140,056	34.82%	262,172	65.18%
2015	398,870	145,747	36.54%	253,123	63.46%
2016	416,580	174,432	41.9%	242,148	58.1%
2017	422,110	183,020	43.4%	239,090	56.6%

Source: West African Examinations Council (2017)

Physics students' achievement at SSCE has remained low over the years. In some years, failure rate in physics is as high as 65%. WAEC (2017) showed that the general results of students that wrote May/June WASSCE Physics examination from 2010 to 2017 had a failure rate above 50%. Low achievement in physics at SSCE is reported to be attributed to difficult topics in physics including thermal energy (Mustafa, 2006). The reasons why most physics students failed thermal energy may be because it contains mathematical concepts which require background knowledge of mathematics principles to solve it. Physics students find it difficult to understand thermal energy due to their poor knowledge of mathematics. Apart from problem of mathematical physics task, the lack of the use of modeling to demonstrate experiment in the class may also affect students' cognition and achievement.

In order to ensure that students excel in thermal energy, over dependent on the use of conventional teaching method by teachers should be prevented. Wood and Gentile (2003) opined that in conventional teaching method, there are no teacher-students interactions as the teacher dominates all the class activities right from the beginning of the lesson to the end. Conventional teaching method also has the attributes of brief teaching, which hinders collaborative thinking that promotes reflection and metacognition. Many researchers opined that conventional teaching method may cause students to results to rote learning and memorization instead of reflective thinking that is more effective in enhancing their cognition (Mustafa, 2006 & Nworgu, 2012). Rote learning hinders students' thinking initiatives during class activities and also prevents them from fully exploring and understanding complex principles in thermal energy. Duyilemi, Olangunju and Olumide (2014) remarked that the overreliance on conventional teaching method in the teaching of physics may affect students' achievement in the subject. Agommuoh and Ifeanacho (2013) pointed out that for teaching to be effective in impacting on students' achievement and retention, the minds of students need to be exposed to varieties of innovative teaching and learning activities that will stimulate students' mental thinking to develop their own cognition. There are varieties of innovative teaching strategies that enhance mental thinking skills and among them is metacognitive scaffolding teaching strategy. Metacognitive scaffolding teaching strategy is a teaching strategy that emanated from the word-scaffolding in the field of construction. Scaffolding is used as a support structure that assists construction workers to execute difficult tasks. Typical scaffolding consists of tightly fitted horizontal, vertical and diagonal members that are either made of wood or steel materials to form a rigid structural framework. In the field of education, these scaffolding members are referred to as teaching models used to assist students solve difficult tasks that are beyond their dependent abilities (Wolf, 2003). These teaching models used to develop students' mental thinking abilities to a higher one that will promote their self cognition is referred to as metacognitive scaffolding teaching strategy.

Also the term metacognitive scaffolding teaching strategy emanated from the concept of metacognition which refers to the cognitive functioning of a person. This cognitive functioning involves series of mental thinking processes involved in knowledge internalization in a learner (Nodoushan, 2008 & Freeman, 2013). Therefore, metacognitive scaffolding teaching strategy can be defined as a teaching framework that utilizes several innovative teaching models used to assist students attain a mental thinking level where they can develop their own cognition needed to solve difficult task. In order to achieve the effect of metacognitive scaffolding teaching strategy several scaffolds models are planned in order to make the teaching of difficult topics easier. These scaffolds according to Many (2002), Denton (2014), Hall (2015) and Wikipedia (2018) may include advanced organizer, modeling, worked examples, explicit and problem solving approach, concept/mind maps, instructing, prompts, hints and questioning. In this study, three teaching models were used in metacognitive scaffolding teaching strategy, the experiment lessons in thermal energy were taught using modeling teaching strategy while mathematical physics lessons were taught using explicit mathematics/problem solving strategy. Advanced organizer was used to introduce physics concepts in thermal energy and then linked to students' prior knowledge. During teaching using modeling and explicit mathematics/problem solving models, the teacher used think aloud and questioning techniques while during problem solving, the teacher further assisted physics students using cueing and hints strategies. Apart from metacognitive scaffolding teaching strategy, the study also investigated the achievement and retention dependent variables. Achievement is the students' scores in a test/examination. Students that have the required grade in an examination were classified as high achievers while students that failed to reach the required grade in an examination were classified as low achievers. The reason for relating metacognitive scaffolding teaching strategy with achievement is that students who had low grade in physics due to their inability to solve difficult questions may get their thinking abilities improved to enable them understand and solve difficult tasks. Metacognitive scaffolding teaching strategy also encourages collaborative thinking between teacher and learners which enable learners to develop their mental thinking to understand difficult topics and task. When students are able to solve difficult tasks their achievement in physics may be enhanced.

Retention is the ability to keep things in memory (Merriam-Webster Dictionary, 2006). It can also be referred to as the mental thinking strength of students to remember what they know after a period of time. Lindstrom and Sharma (2011) emphasized that human memory is large enough to store knowledge for remembrance and the storage capacity may be limited when students did not understand and recall what they are taught. In order to understand and retrieve what has been learnt after a period of time, students had to think through what they have learnt in order to internalize it in their mind. Therefore Metacognitive scaffolding teaching strategy may help improve student's retention by creating an interactive atmosphere for creative and reflective thinking that enable knowledge to be stored inside the mind of students through thinking. This stored knowledge enables students gain mastery and retain knowledge. Omwirhiren (2015) opined that retention may be limited by the use of conventional teaching method and poor retention in physics has been the cause of students' low achievement in the SSCE. Investigation into the effect of metacognitive scaffolding teaching strategy showed that it has a positive effect on students' learning outcome (Azevedo & Hadwin, 2005). James and Okpala (2010) also found that metacognitive scaffolding teaching strategy had significant effect on students' literacy skills in reading comprehension. Metacognitive scaffolding teaching strategy has also been reported to be effective in solving difficult task in design problem solving and analytical skills in other subject areas, but not many studies have reported its effect in physics. It is in view of this, that this study investigated the effect of metacognitive scaffolding teaching strategy on senior secondary physics students' achievement and retention in thermal energy in Federal Capital Territory, Abuja, Nigeria.

Research Questions

The following research questions guided the study:

1. What are the mean achievement scores of physics students taught thermal energy using metacognitive scaffolding teaching strategy and those taught using conventional teaching method?
2. What are the mean retention scores of physics students taught thermal energy using metacognitive scaffolding teaching strategy and those taught using conventional teaching method.

Hypotheses

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

H_{01}: There is no significant difference in the mean achievement scores of physics students taught thermal energy using metacognitive scaffolding teaching strategy and those taught using conventional teaching method.

H_{02}: There is no significant difference in the mean retention scores of physics students taught thermal energy using metacognitive scaffolding teaching strategy and those taught using conventional teaching method.

Methodology

Quasi-experimental research design involving non randomized control group pretest-posttest design was used as the research design for the study. It employed non randomized control group pretest-posttest design deals with the use of intact classes. Two intact classes from two senior secondary two (SSII) offering physics were randomly assigned to control and experimental groups. Before the treatment was carried out, pretest was given to the two sampled schools, then the control and experimental groups were exposed to metacognitive scaffolding teaching strategy and conventional teaching method respectively for a period of eight weeks. After eight weeks, posttest which contains the same questions as the pretest was administered to the two sampled schools after the treatment. The pretest questions were reshuffled as retention test and administered after four weeks. The population of the study consisted of two thousand six hundred and ninety nine (2699) SSSII physics students (1609 male and 1090 female) from fifty four Senior Secondary Schools that are public and co-educational in Federal Capital Territory (FCT), Abuja. A sample size of seventy five (75) SSII physics students from two intact physics classes (40 and 35 physics students) were selected out of a population of 2699 SSII physics students in FCT-Abuja using multistage random sampling.

The instrument for data collection consists of Thermal Energy Achievement Test (TEAT). The TEAT was used to measure physics students' achievement in thermal energy. The questions were adapted from SSCE past questions and contains questions on temperature and its measurement, thermometer, absolute scale of temperature, specific heat capacity, latent heat capacity, evaporation, boiling and sublimation and relative humidity and dew points. The TEAT was given to two science education experts and one measurement and evaluation expert for validation. The reliability of TEAT was determined by trial testing with Government Secondary School (GSS) 2, Jikwoyi in FCT-Abuja. The data collected were analyzed using Kuder-Richardson $(K\text{-}R)_{21}$ to obtain a reliability coefficients of 0.92. Physics students in the experiment group were taught using metacognitive scaffolding teaching strategy, while physics students in the control group were taught using conventional teaching method. Both groups were taught for eight weeks. At the end of the eight weeks, TEAT was administered as posttest to physics students in the two groups. After four weeks TEAT was administered as Thermal Energy Retention Test (TERT). The data collected were analyzed using Statistical Package for Social Science (SPSS) model. The research questions were answered using mean and standard deviation, while the hypotheses were tested using Analysis of Covariance (ANCOVA) at 0.05 level of significance.

Results

Research Question 1: What are the mean achievement scores of physics students taught thermal energy using metacognitive scaffolding teaching strategy and those taught using conventional teaching method?

Table 3: Means and Standard Deviations of Achievement Scores of Physics Students Taught Using Metacognitive Scaffolding Teaching Strategy and Conventional Teaching Method

Groups	Tests	N	Mean	SD	Relative SD	Standard Error
Treatment	Pretest	30	23.55	6.356	0.233	1.344
	Posttest	30	26.30	8.510	0.324	1.554
Control	Pretest	36	20.19	9.760	0.567	1.784
	Posttest	36	21.25	10.061	0.474	1.677

Table 3 indicates that the mean achievement scores of physics students in the treatment group were higher than the mean achievement scores of their control group counterparts. The relative standard deviations of the treatment group were lower than their control group counterpart. This shows that the control group had physics scores that are more widespread and in agreement with the mean than the treatment group.

Research Question 2: What are the mean retention scores of physics students taught thermal energy using metacognitive scaffolding teaching strategy and those taught using conventional teaching method?. The pretest, retention mean scores and standard deviation from the treatment and control groups were analyzed and compared. Summary of result of data analysis is presented in Table 4.

Table 4: Means and Standard Deviations of Retention Scores of Physics Students Taught Using Metacognitive Scaffolding Teaching Strategy and Conventional Teaching Method

Groups	Tests	N	Means	SD	Relative SD	Standard Error
	Pretest	30	25.47	7.653	0.298	1.329
Treatment	Retention	30	27.87	7.794	0.280	1.423
	Pretest	36	21.23	9.875	0.4679	1.675
Control	Retention	36	20.36	9.978	0.490	1.663

Table 4 shows that the mean retention score of physics students in the treatment group were higher than the mean retention score of physics students in the control group. The relative standard deviations of the control group were higher than that of the treatment group. This shows that the control group had physics scores that are more widespread and in agreement with the mean than the treatment group.

Hypothesis 1: There is no significant difference in the mean achievement scores of physics students taught thermal energy using metacognitive scaffolding teaching strategy and those taught using conventional teaching method.

Table 5: ANCOVA of the Mean Achievement Scores of Physics Students taught Using Metacognitive Scaffolding Teaching Strategy and Conventional Teaching Method

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	4939.977[a]	2	2469.988	138.889	.000
Intercept	803.357	1	803.357	45.173	.000
Pretest	4522.663	1	4522.663	254.312	.000
Group	370.555	1	370.555	20.837	.000
Error	1120.387	63	17.784		
Total	42650.000	66			
Corrected Total	6060.364	65			

a. R Squared = .815 (Adjusted R Squared = .809)

Table 5 shows that at the group level, the p significant value of 0.000 is less than p at 0.05 level of significance ($p<0.05$). Based on this result, the null hypothesis is therefore rejected. This implies that there was a significant difference in the achievement scores of physics students taught thermal energy using metacognitive scaffolding teaching strategy and those taught using conventional teaching method in favour of those taught using metacognitive scaffolding teaching strategy.

Hypothesis 2: There is no significant difference in the mean retention scores of physics students taught thermal energy using metacognitive scaffolding teaching strategy and those taught using conventional teaching method.

Table 6: ANCOVA of the Mean Retention Scores of Physics Students Taught Using Metacognitive Scaffolding Teaching Strategy and Conventional Teaching Method.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	5776.327a	2	2888.163	465.042	.000
Intercept	36.847	1	36.847	5.933	.018
Pretest	4854.508	1	4854.508	781.656	.000
Group	121.312	1	121.312	19.533	.000
Error	391.264	63	6.211		
Total	43467.000	66			
Corrected Total	6167.591	65			

a. R Squared = .937 (Adjusted R Squared = .935

Table 6 shows that at the group level, the p significant value of 0.000 is less than p at 0.05 level of significance ($p<0.05$). Based on these results, the null hypothesis is therefore rejected. This implies that there was a significant difference in the retention scores of physics students taught thermal energy using metacognitive scaffolding teaching strategy and those taught using conventional teaching method in favour of the former. Thus, with the use of metacognitive scaffolding teaching strategy in physics, students are most likely to retain more physics concepts than those taught using conventional method of teaching.

Discussion

The result from hypothesis 1 showed that physics students had a better achievement scores in their achievement scores when taught thermal energy using metacognitive scaffolding teaching strategy than their counterpart who were taught using the conventional teaching method. This finding is in agreement with those of Fouche (2013), Jayapraba and Kanmani (2015) and Uzoechi and Gimba (2015) who reported that metacognitive instructional strategy improved students' achievement compared with the conventional teaching method. The reason for this finding might be that metacognitive scaffolding teaching strategy helps in improving the quality of instruction and students' innovative thinking skills that might have led to better achievement scores in thermal energy. The result from hypothesis 2 revealed that physics students had a better retention scores when taught thermal energy using metacognitive scaffolding teaching strategy than their counterpart who were taught using the conventional teaching method. This finding agrees with that of Adodo (2013) who established that mind mapping metacognitive strategy was more effective for better retention performance. The reason for this finding might be that students did not understand the lessons using concept mapping and guided discovering integrated teaching approach.

Conclusion

Based on the findings of the study, it is concluded that Physics students taught using metacognitive scaffolding teaching strategy had higher achievement scores and retention scores than their counterpart taught using the conventional teaching method. This shows that metacognitive scaffolding teaching strategy is more effective in teaching thermal energy than the use of the conventional teaching method.

Recommendations

Based on the findings of the study, it is recommended that:

1. Physics teachers should be encouraged to teach physics using metacognitive scaffolding teaching strategy for classroom instruction in both single and coeducational schools.
2. Curriculum planners and developers should consider the introduction of metacognitive scaffolding teaching strategy in senior secondary school physics curriculum.
3. Educational agencies should organize workshops, seminars and conferences for training physics teachers on the application of metacognitive scaffolding teaching strategy.

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