International Journal of Scientific Advances
ISSN: 2708-7972
Volume: 1 | Issue: 2 | Sep - Oct 2020 Available Online: www.ijscia.com

Effect of Metacognitive Scaffolding Teaching Strategy on Secondary School Physics Students' Achievement and Attitude to Thermal Energy

P.A. Agu* and C.O. Iyamu

Faculty of Education, Nasarawa State University, Keffi, Nigeria
E-mail: Ashlameagu@yahoo.com; Caesariyamu71@Gmail.Com
*Corresponding author details: Assoc. Prof. P.A. Agu, Ashlameagu@yahoo.com

ABSTRACT

This study investigated the effect of metacognitive scaffolding teaching strategy on secondary school physics students' achievement and attitude to thermal energy in Federal Capital Territory (FCT), Abuja, Nigeria. The study asked two research questions and postulated two null hypotheses which were tested at 0.05 level of significance. Quasi experimental research design involving non randomized control pretest-posttest design was utilized. The study population consisted of 2,699 Senior Secondary II (SSII) physics students from 54 public SSII physics students in FCT, Abuja. Multistage random sampling technique was used to select two intact classes having 75 SSII physics students from two SS as sample for the study. Two instruments consisting of Thermal Energy Achievement Test (TEAT) and Attitude to Thermal Energy Questionnaire (ATEQ) were used for data collection. The data collected from these instruments 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 physics students taught using metacognitive scaffolding teaching strategy performed better than those physics students taught using conventional teaching method. Also, physics students taught using metacognitive scaffolding teaching strategy had better attitude towards thermal energy than their counterparts 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; Attitude; conventional lecture method

INTRODUCTION

Science is the study of the natural world and contains several bodies of knowledge that has laws, facts, principles, concepts and conventions associated with it (Faye and Mclean, 2014). These several bodies of knowledge are segmented into several studies that include physics, chemistry and biology. Physics as a body of science knowledge is concerned with matter and energy and the relationship between them (Okeke & Akande, 2008). The knowledge of physics can be applied in the field of agriculture, automobile, refrigerator, air-conditioning, water supply, irrigation, civil works, electrical and electronics. Many inventions emanating from these fields which require the knowledge of physics for their understanding consist of electric kettle, petrol engine, diesel engine, jet engine, clinical thermometer, electric bulbs, X-ray machine, camera, car, radio, computer, television, batteries, refrigerators, air conditioners, 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 dwindling over the years.

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

Year	Total Entry	Pass Grade Levels (A1-C6)	%	Fail Grade Levels (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 fail thermal energy may be because it contains mathematical concepts which require background knowledge of mathematics principles to solve it. Therefore, 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 lecture method by teachers should be minimized. Wood and Gentile (2003) opined that in conventional lecture 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 lecture method also has the attributes of brief teaching, which hinders collaborative and critical thinking that promotes reflection and metacognition. Many researchers have opined that conventional teaching method may cause students to resort to rote learning and memorization instead of reflective thinking that is more effective in enhancing their cognition (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 lecture 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 to impact 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- scaffold that is used in the field of construction. Scaffolding is used as a support structure that assists construction workers to execute difficult task. 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 beyond their dependent abilities (Wolf, 2003). These teaching models when used to develop students' mental thinking abilities to a higher one that would promote their self-cognition, they are 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 tasks. In order to achieve the effect of metacognitive scaffolding teaching strategy, several scaffolds or models are planned in order to make the teaching of difficult topics easier. These scaffolds according to Many (2002), Denton (2014) and Hall (2015) 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 attitude dependent variables. Achievement refers to students' scores in a test/examinations. 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 grades in physics due to their inability to solve difficult questions may get their thinking abilities improved upon to enable them understand and solve difficult tasks. Metacognitive scaffolding teaching strategy also encourages collaborative thinking between teacher and learners which enable learners 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.

Attitude is defined as an internal desire of a person which dictates the choice of his personal actions towards a thing. Cracker (2006) defined attitude as a persons' mental state in respect to what he thinks about a particular subject. A person who thinks positively towards a subject is likely to be determined and actively participate in classroom activities than a person who thinks negatively. Positive thinking also enables students to think through what they understand in a topic and also reflect on it. Attitude also brings about the stimulant for the acquisition of knowledge. Since metacognitive scaffolding teaching strategy is geared towards creative and reflective thinking, students may get interested in difficult topics and modify their thinking to positive ways. Jbeili (2012) posited that metacognitive scaffolding teaching strategy assists students to manage their thinking and adjust to positive ways when they are confused. An and Cao (2014) reported that metacognitive scaffolding teaching strategy improves students' metacognition through knowledge planning, monitoring and evaluation. Metacognitive scaffolding teaching strategy has been shown to enhance students' metacognitive learning skills (Wolf, 2003). Another finding into the effect of metacognitive scaffolding teaching strategy also showed that it has a positive effect on students' learning outcome (Azevedo & Hadwin, 2005). James and Okpala (2010) found that metacognitive scaffolding teaching strategy had significant effect on students' literacy skills in reading comprehension. Metacognitive scaffolding teaching strategy has 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. However, it is in view of this, that this study investigated the effect of metacognitive scaffolding teaching strategy on senior secondary physics students' achievement and attitude to thermal energy in Federal Capital Territory, Abuja, Nigeria.

RESEARCH QUESTIONS

The following research questions guided the study:

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

ii. What are the mean attitude scores of physics students towards thermal energy taught using metacognitive scaffolding teaching strategy and those taught using conventional lecture method?

HYPOTHESES

The following null hypotheses were tested in the study.

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 lecture method.

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

METHODOLOGY

This research design for this study consists of quasi-experimental research design involving non randomized control group pretest-posttest design. It employed non randomized control group pretest-posttest design which deals with the use of intact classes. Two intact classes from two senior secondary two (SSII) offering physics were randomly assign to control and experimental groups. Before embarking on the treatment, pretest were giving to the two sampled schools, then the control and experimental groups were exposed to metacognitive scaffolding teaching strategy and conventional lecture method respectively for a period of 8 weeks. After 8 weeks, posttest which contained the same questions as the pretest was administered to the two sampled schools after the treatment. The study population consisted of 2699 SSSII physics students (1609 male and 1090 female) from 54 Senior Secondary Schools that are public and co-educational in Federal Capital Territory (FCT), Abuja. A sample size of 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 consisted of Thermal Energy Achievement Test (TEAT) and Attitude to Thermal Energy Questionnaire (ATEQ). The TEAT which had 50 test items 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. ATEQ was used to measure physics students' attitude towards thermal energy and it contains twenty statements structured in accordance with 4 points Likert-type rating scale format. The TEAT and ATEQ were given to two science education experts and one measurement and evaluation expert for validation. The reliability of TEAT and ATEQ were determined by trial testing in a school outside the sampled schools within the population area in FCT-Abuja. The data collected were analyzed using Kuder-Richardson $(K\text{-}R)_{21}$ and Cronbach's Alpha Reliability methods to obtain reliability coefficients of 0.92 and 0.79 for TEAT and ATEQ respectively.

Physics students in the experimental group were taught using metacognitive scaffolding teaching strategy, while physics students in the control group were taught using conventional lecture method. Both groups were taught for eight weeks. At the end of the eight weeks, TEAT and ATEQ were administered as posttest to physics students in the two groups. The data collected from the instruments 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.

RESULT

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 lecture method?

The data that answered this research question is presented in table 2.

TABLE 2: Means and Standard Deviations of Achievement Scores of Physics Students Taught Using Metacognitive Scaffolding Teaching Strategy and Conventional Lecture 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 2 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. This implies that students who were taught using metacognitive scaffolding teaching strategy performed better than their counterparts in the lecture method.

Research Question 2: What are the mean attitude scores of physics students towards thermal energy taught using metacognitive scaffolding teaching strategy and those taught using conventional lecture method?

The data that answered this research question is presented in table 3.

TABLE 3: Means and Standard Deviations of Attitude Scores of Physics Students taught using Metacognitive Scaffolding Teaching Strategy and Conventional Lecture Method

Groups	Tests	N	Means	SD	Relative SD	Standard Error
	Pre-Attitude	30	58.41	4.125	0.105	1.012
Treatment	Post-Attitude	30	63.87	4.238	0.066	1.018
	Pre-Attitude	36	42.65	6.234	0.134	0.634
Control	Post-Attitude	36	46.25	5.575	0.125	0.706

Table 3 indicates that the mean attitude score of physics students in the treatment group were higher than the mean 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 of the treatment group. This implies that physics students who were taught using metacognitive scaffolding teaching strategy had a more positive attitude towards thermal energy than their counterparts in the lecture method.

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 lecture method.

The result of this test is presented in table 4.

TABLE 4: ANCOVA Analysis of the Mean Achievement Scores of Physics Students taught Using Metacognitive Scaffolding Teaching Strategy and Conventional Lecture 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 4 shows that at the group level, the P significant value of 0.000 is lesser 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 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 attitude scores of physics students towards thermal energy taught using metacognitive scaffolding teaching strategy and those taught using conventional teaching method.

The result of this test is presented in table 5.

TABLE 5: ANCOVA Analysis of the Mean Attitude Scores of Physics Students to Thermal Energy Taught Using Metacognitive Scaffolding Teaching Strategy and Conventional Lecture Method

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	4353.714[a]	2	3246.025	415.032	0
Intercept	57.657	1	48.738	6.159	.001
Pretest	3798.433	1	5437.347	674.387	.000
Group	196.426	1	145.301	18.278	.000
Error	474.354	63	5.209		
Total	48597.132	66			
Corrected Total	6587.468	65			

a. R Squared = .898 (Adjusted R Squared = .890)

Table 5 shows that at the group level, the P significant value of 0.000 is lesser than P at 0.05 level of significance ($P<0.05$). The null hypothesis is therefore rejected. This implies that there was a significant difference in the attitude of physics students towards thermal energy taught using metacognitive scaffolding teaching strategy and those taught using conventional teaching method. In essence those taught using metacognitive scaffolding teaching strategy would developed more positive attitude to the study of thermal energy and physics in general more than those taught using the 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) where they reported that metacognitive instructional strategy improved students' achievement compared with the conventional lecture method. The reason for this finding might be attributed to the fact that metacognitive scaffolding teaching strategy helped in improving the quality of instruction and students' innovative thinking skills which might have led to better achievement scores in thermal energy. The result from hypothesis 2 showed that physics students had more positive attitude to thermal physics when taught using metacognitive scaffolding teaching strategy than their counterpart who were taught using the conventional lecture method. This finding agrees with the outcome of Sonleitner (2005) whose finding showed that there was a positive relationship between students' achievement score and their attitude. The reason for this finding could be that metacognitive scaffolding teaching strategy which engages students in collaborative thinking had an impact on students' thinking ability which might have also changed their attitude towards physics.

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 more positive attitude to physics than their counterpart taught using the conventional lecture method. This shows that metacognitive scaffolding teaching strategy is more effective in teaching thermal energy than the use of the conventional lecture method.

RECOMMENDATIONS

The study therefore recommends that:

1. Physics teachers should be encouraged to teach physics concepts using metacognitive scaffolding teaching strategy 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.

REFERENCES

[1] Agommuoh, P.C. & Ifeanacho, A.O.(2013). Secondary school students' assessment of innovative teaching strategies in enhancing achievement in physics and mathematics. IOSR Journal of Research & Method in Education, Vol. 3, Issue 5 (Nov. -Dec. 2013), 6-11.

[2] An, Y., & Cao, L. (2014) Examining the effects of metacognitive scaffolding on students' design problem solving and metacognitive skills in an

[3] online environment. MERLOT Journal of Online Learning and Teaching, 10(4), 552-561.

[4] Azevedo, R., & Hadwin, A. F. (2005). Scaffolding self-regulated learning and metacognition: Implications for the design of computer-based scaffolds. Instructional Science, 33 (5&6), 367–379.

[5] Cracker, D.A. (2006). Attitudes toward science of students enrolled in introductory level science courses at UW-La Crosse. Journal of Undergraduate Research, 9, 15-21.

[6] Denton, D.W. (2014). Characteristics of scaffolding and activities for using it in classroom. Washington State Association for Supervision and Curriculum Development.

[7] Duyilemi, A.N., Olangunju, A.M., & Olumide, O.J. (2014). Effect of computer simulation package, gender and parental education on Nigerian secondary school students' attitude towards biology. A paper presented at the 21st Century Academic Forum Conference Proceedings at 2014 Conference at Harvard.

[8] Faye, O., & Mclean, J. (2014). Innovate: A blueprint for science, technology, engineering and mathematics in California public education. Retrieved January 5, 2016 from http://www.cde.gov/pd/ca/sc/documents/innovate.

[9] Fouche, J. (2013). The effect of self-regulatory and metacognitive strategy instruction on impoverished students' assessment achievement in physics. A Published Dissertation Presented in Partial Fulfillment of the Requirements for the Degree of Doctor of Education, Liberty University, Lynchburg, VA.

[10] Fraser, B.J., & Walberg, H.J. (2005). Improving science education. National Society for the Study of Education (NSSE), Illinois.

[11] Freeman, S.M. (2013). Effect of the solve strategy on mathematical problem solving skills of secondary students with learning disabilities. A published Ph D thesis of the University of North Carolina, Charlotte.

[12] Hall, A. (2015). Instructional scaffolding to improve learning. Spring 2018 Spectrum Newsletter, Faculty Development and Instructional Design Centre, Northern Illinois University.

[13] James, I. & Okpala, C.O. (2010). The use of metacognitive scaffolding to improve college students' academic success. Journal of College Teaching and Learning, 7(11), 47-50.

[14] Jayapraba, G. & Kanmani, M. (2015). Effect of metacognitive strategy on jigsaw cooperative learning method to enhance biology achievement. The Online Journal of New Horizons in Education, 4(2), 47-57.

[15] Jbeili, I. (2012). The effect of cooperative learning with metacognitive scaffolding on mathematics conceptual understanding and procedural fluency. International Journal for Research in Education,32, 13-19.

[16] Many, J. E. (2002). An exhibition and analysis of verbal tapestries: Understanding how scaffolding is woven into the fabric of instructional conversations. Reading Research Quarterly, 37, 376–407.

[17] Mustafa, B. (2006). Fostering conceptual change by cognitive conflict based instruction on students' understanding of heat and temperature concepts. Eurasia Journal of Mathematics, Science and Technology Education, 2(2), 43-56.

[18] NERDC(2012). Physics for senior secondary school. Nigerian Educational Research and Development Council.

[19] Nodoushan, M.A.S. (2008). The role of metacognition in the language and teaching profession. I-Manager's Journal on Educational Psychology, 2(1).

[20] Norah, O., & Orobosa, A. (2009). Persistent Gender Inequality in Nigerian Education. Paper presented on December, 2, 2010 at Benson Idahosa University, Benin-City, Nigeria.

[21] Nworgu, L.N. (2012). Metacognitive instructional approaches: Implications for the implementation of senior secondary school biology curriculum. Keffi Journal of Educational Studies, 3(1), 114-125.

[22] Okeke, P.N., Okeke, F.N., & Akande, S.F. (2008). Senior secondary physics. Ibadan: Macmillan Nigeria Publishers Limited.

[23] Saage, O. (2009). Causes of mass failures in mathematics examination among students. A commissioned Paper Presented at Government Secondary School, Karu, Abuja.

[24] Sonleitner, C.L. (2005). Metacognitive strategy use and its effect on college biology students' attitude toward reading in the content area. A Published Master of Science Thesis from the Faculty of Graduate College of the Oklahoma State University, Oklahoma.

[25] Uzoechi, B.C., & Gimba, M. (2015). Gender difference in achievement among secondary school students taught physics concepts using metacognitive instructional technique. Keffi Journal of Educational Studies, 4(1), 72-75.

[26] WAEC (2016). Executive summary of entries, results and chief examiners' reports on the West African senior school certificate examination. WAEC Headquarter, Lagos.

[27] Wolf, S. (2003). The big six information skills as a metacognitive scaffold: A case study. Research Journal of the American Association of School Librarians, 6, 121-146.

[28] Wood, W. B., & Gentile, J. M. (2003). Teaching in a research context. Science Educational Journal, 302:1510.