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Effect of Capacitor-Aided System for Teaching and Learning Electricity on the Remediation of Misconceptions in Electric Circuit among Secondary School Students in Rivers State.

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Abstract

This study investigated the effect of Capacitor-Aided System for Teaching and Learning Electricity (CASTLE) model on the remediation of misconceptions in electric circuit among secondary school physics students in Rivers State. The study employed a quasi-experimental design. The population of the study was 608,789 senior secondary school physics students in co-educational public senior secondary schools in Rivers State. Two intact classes were randomly sampled from each school. A total of 156 SS2 physics students (97 male and 59 female) from four intact classes participated in the study. Two research questions guided the study. The instrument used in gathering data for the study was a four-tier multiple choice diagnostic test titled "Electric Circuit Diagnostic Four-tier Test" which had a reliability coefficient of 0.81 and 0.78 respectively. The research questions were answered using a descriptive statistics of mean and standard deviation. The corresponding hypotheses were tested using Analysis of Covariance and Z-test at 0.05 level of significance Results from the study revealed that there was reduction in students' misconception and consequently an increase in students' scientific conception in electric circuit amongst students whose misconceptions were remediated using CASTLE model than those remediated using Lecture method. The study also revealed the CASTLE model helped in increasing scientific conception and consequent reduction in students' misconceptions in electric circuit amongst the male student than the female students. Based on the findings of the study, it was recommended that physics teachers should be given adequate training on how to effectively use this pedagogical approach in teaching electric circuit.

Introduction

Studies have shown that electric circuit is one of the topics where students have learning difficulties and a lot of alternative conception which is not in consonant with scientific conception (Pesman, & Eryilmaz, 2010, Soeharto, et al., 2019; Shepardson & Moje, 2013, Adolphus & Agbesor, 2008). This is due to the abstract nature of the concept of electric current (Kaltakci, 2012). Students know that current flows through a conductor, but seem not understand how it flows and what is making it flow; it is invisible. This makes student susceptible to a lot of unscientific imagination that sometimes lead to alternative conception otherwise known as misconception. If these misconceptions are not properly diagnosed and remediated to enhance proper teaching and learning the concept, students would leave the lesson haven been taught and seemingly understood, but still hold on to their own ideas (alternate conception) about ‘what is really happening’ (Harlen & Qualter, 2006).

Every individual holds a personal understanding and interpretation of events in the world which is maintained as “personal idea” and held tenaciously as true, because they represent products of personal experience. Students usually come to the classroom with this “personal idea” which often interfere with the concept presented by the teacher during a lesson and inhibit proper understanding which often bring about concept difficulty and consequently result to students’ poor performance in examinations. In the process of attempting to overcome difficulty in understanding, most students usually create from their “prior knowledge” which sometimes is different from scientific conceptions. These scientifically unacceptable ideas are called “misconceptions”. Others refer to it as naïve conceptions, alternative conceptions, alternative framework, intuitive theories, children science, preconception (Taber, 2011; Champagne et al, 1982).

Several definitions have been offered to the term “misconception” by different authors. Sanger and Greenbowe (1996) define misconception as student’s conceptual and prepositional knowledge that is inconsistent with or different from commonly accepted scientific consensus. Scientific misconceptions are commonly held beliefs about science that have no basis in actual scientific facts. It can also be referred to as preconceived notions based on cultural and/or religious influence (Frankline, 2017). Misconceptions are very difficult to extinguish and constitute a major problem to teaching and learning of science. According to Milligan and Wood (2010), misconceptions interfere with the teaching and learning process and hinder assimilation and accommodation of knowledge. It provides a barrier to students’ conceptual understanding which result in perceived concept difficulty and negative attitude to science subject (Tsaparlis et al., 2019). Generally, efforts by teachers to change students’ misconception are usually met with great resistance because they are embedded in the students’ cognitive structure. When teachers provide instruction on concept in various subjects, they are teaching students who already have some pre- instructional knowledge about the topic. Students’ knowledge however can be erroneous, illogical or misinformed. Students quite naturally form ideas from everyday experience which are not in consonant with scientific concepts. Moreover, some concepts are simply very difficult to grasp. They may be very abstract, counterintuitive or quite complex. Hence, students’ understanding of these concepts is flawed. Most times students generally are unaware that the knowledge they have is wrong. Moreover, misconception can be very entrenched in students thinking. In addition, students interpret new experiences through these erroneous understandings thereby interfering with being able to correctly grasp new information.

The problem of misconception in science can be traced to different causes which may be teacher or student related. Some of these are: inappropriate teaching method, abstract nature of scientific concepts, analogies, students’ personal experience and belief (Hanson, 2015; Unal et al., 2010; Kazembe, 2010). Apart from the aforementioned reasons, some school teachers serve as potential source of erroneous ideas because of their poor knowledge of the concept they teach students. Such teachers may hold several misconceptions about scientific concepts and transfer same to students during lesson. Regrettably, most of these teachers apart from being unaware of these misconceptions are not interested in scientific conceptions, rather they oversimplify basic concept in order to facilitate students understanding which eventually result to misconceptions.

The use of carefully designed and innovative teaching strategies to remediate misconception can be very useful in helping students to construct new ideas which are “scientifically acceptable” from their previous ideas (Taber, 2011). However, several instructional strategies and models have been suggested to be effective in achieving conceptual change and helping student leave their alternative conceptions behind and learn correct concepts or theories. These models and strategies includes; verbalization of misunderstandings, metacognitive strategies, concept mapping, anchoring conception, analogical reasoning amongst others (Dykstra et al., 1992; Scot, et al., 1991). There is no common instructional strategy for all misconceptions. It varies according to the nature of concept.

The Capacitor-Aided System for Teaching and Learning Electricity (CASTLE) project otherwise known as Electricity Visualized is a new high-school electricity module developed by a team of high school and college physics teachers in the USA with National Science Foundation Support. It was motivated by researches on students’ misconceptions and conceptual difficulties in electricity, and employs instructional materials developed in response to those researches. These researchers also came up with a CASTLE equipment kit which contains materials needed for investigating circuit of light, bulbs and capacitor which provide means for hands-on experiment which enables students to:

1. Investigate the mechanism for current propulsion
2. Confront their misconceptions of electric circuits
3. Construct qualitative models for circuit concepts
4. Invent an intuitive conception of electric potential
5. Revise their models for transfer to electrostatic

Steinberg (2004) pointed out that the Capacitor-Aided System for Teaching and Learning Electricity (CASTLE) contains instructional materials, homework, and quizzes for challenging common misconception in electric circuit and enhancing conceptual understanding of electricity. It is designed to engage students’ interest through hands-on investigation, overcome misconceptions that inhibit learning and reasoning, and foster development of effective explanatory models. It provides a complete introductory module that can replace the sections on electricity in textbooks. It assumes no prior knowledge of electricity and is appropriate for all students of high school age - in standard, honors, and AP physics, as well as in physical science, electronics and technology education. The heart of the CASTLE module is a sequence of experiments with light bulbs, batteries, and specially designed capacitors. In A Guide to Introductory Physics Teaching, Steinberg (2004) explains the key role of the capacitors in helping students build models and revise them toward greater explanatory power: With these capacitors in the circuits, one can observe transient lighting of the bulbs as the capacitors are charged and discharged. This additional ingredient enormously extends the number of questions that can be asked and answered about location and displacement of charge and greatly enhances the soundness and completeness with which the current model can be constructed."

Enabling students to recognize and overcome their misconceptions is an essential part of the CASTLE approach to building a model that predicts and explain the behavior of electric circuit (Steinberg & Wainwright, 1993). For example, nearly all students believe that the invisible substance moving in an operating circuit originates exclusively in the battery ("battery as the power source"). Charging and discharging a capacitor through light bulbs challenges this misconception and provides the stimulus that begins disturbing students' idea about what happens in a circuit. During charging, compass deflections shows movement in all wires briefly in the same circuital direction as in a steady-state circuit. But students know that there is a layer of insulator between the plates and therefore charge cannot move within the capacitor from one plate to the other. It is evidence in literature that CASTLE model is amongst the eclectic arrays of pedagogical approaches that are found effective in conceptual change in students' conception of electricity. (Wainwright, 2019)

Statement of Problem

Research findings have shown that electric circuit is one of the topics in secondary school physics curriculum that students find difficult to grasp due to the complex and abstract nature of the concept (Gaigher, 2014). Students' misconceptions have been identified as one of the major causes of difficulty in students understanding of electric circuit (Soeharto *et al.*, 2019; Shepardson & Moje, 2013; Heller & Finley, 1992). Consequently, this could have led to students' lack of understanding and poor performance in questions relating to electric circuit (Moodley & Gaigher, 2019). Studies on the identification and remediation of students' misconceptions in electric circuit have been reported in international literatures with most of the studies conducted outside Nigeria. The misconceptions elicited could be peculiar to the students because of some locally prevailing factors such as beliefs, metaphors, instructional environment, amongst others (Ivowi & Oladotun, 2006).

Hence, it is pertinent to diagnose misconceptions of students in electric circuit in Rivers State and test the effectiveness of instructional methods developed out of an eclectic array of strategies tried and found effective elsewhere by researchers to remediate misconceptions. There is therefore, a need to ascertain the effect of the CASTLE (Capacitor-Aided System for Teaching and Learning Electricity) model on the remediation of identified misconceptions electric circuit in senior secondary schools in Rivers State.

Purpose of the Study

The purpose of this study is to determine the effect of CASTLE model on the remediation of misconceptions in electric circuit among secondary school physics students in Rivers State. Specifically, the study determined:

1. the effect of CASTLE (Capacitor-Aided System for Teaching and Learning Electricity) model on the remediation of students' misconceptions in electric circuit.

2. the effect of CASTLE (Capacitor-Aided System for Teaching and Learning Electricity) model on the remediation of male and female students' misconceptions in electric circuit.

Research Questions

The following research questions guided the study;

1. What is the effect of CASTLE (Capacitor-Aided System for Teaching and Learning Electricity) model and Lecture method on the remediation of students' misconceptions in electric circuit?

2. What is the effect of CASTLE (Capacitor-Aided System for Teaching and Learning Electricity) model on the remediation of male and female students' misconceptions in electric circuit?

Hypotheses

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

H_{01}: There is no significant difference in the mean scores of students whose misconception in electric circuit were remediated using CASTLE model and those remediated using lecture method

H_{02}: There is no significant difference in the mean scores of male and female students whose misconceptions in electric circuit were remediated using CASTLE model.

Methodology

The study adopted a quasi-experimental design, specifically the non-randomized non-equivalent pre-test post-test control group design.

The population of the study comprises all the 608,789 senior secondary school physics students in public co-educational senior secondary schools in Rivers State. A multistage sampling procedure was adopted for the study. Purposive sampling was used to select two Local government areas from the 23 local government areas in Rivers State precisely Obio/Akpor and Gokana Local government areas. These local government areas were those that the researcher is familiar with the terrain. Two schools were purposively sampled for the study; one from 16 co-educational public schools in Obio/Akpor Local government area and one from 10 co-educational public schools in Gokana Local government area; one school from each local government area. The criteria for the selection of the schools were:

- Schools that are co-educational
- Schools with functional and adequately equipped physics laboratory.
- Schools having at least two qualified physics teacher with at least five years teaching experience. (Steinberg & Wainwright,1993).

Two intact classes were randomly sampled for the study in each school making it a total of four intact classes which consist of 156 students that were used for the study. In each school, the two classes were randomly assigned a teaching strategy (CASTLE model or Lecture method) for the remediation of the misconceptions held by students.

Data were obtained using a four-tier diagnostic test instrument. The instrument was titled "Electric Circuit Diagnostic Four-tier Test" (ECDFT). The researcher adapted the Three-Tier Electric Circuit Diagnostic Test developed by Pesman and Eryilmaz (2010), and did a mild modification on it to a Four-Tier diagnostic Test by adding another confidence level for the chosen reason in the third tier. Literatures have recommended that four-tier diagnostic test is better amongst other tools in diagnosing misconceptions in science education (Kaltakci, 2012; Fariyani et al., 2017; Caleon & Subramaniam, 2010).

The Four-tier misconception diagnostic test was preferred in this study over other misconception test such as one-tier, two-tier and three-tier test because it addresses some weaknesses in the other test instruments on misconception such as, errors due to over estimation of students misconception scores and the correct score, underestimation of lack of knowledge proportion and guessing (Guriel & Eryilmaz, 2015).

The instruments were subjected to face and content validity by experts in physics education and experts in measurement and evaluation before it was adopted for the study. The reliability of the instrument was determined through a test-retest method for a measure of its stability and kuder-Richardson-20 for it internal consistency. This was achieved through a pilot testing on 15 students who were randomly sampled from a school not used in the study area. The instruments were administered, the students responded to the instruments and it was retrieved. In other to control memory effect or testing effect which is an envisaged weakness of test-retest method, the items on the instrument were reshuffled, an interval of two weeks was allowed between the first test and the second administration of the test. The initial and retest scores were correlated using Pearson Product Moment. A correlation coefficient of 0.81 was obtained as a measure of stability of the instrument. To ascertain the internal consistency of the instrument, kuder-Richardson-20 reliability was used and a coefficient (r) of 0.78 was obtained.

The instrument (ECDFT) was administered to students in both the experimental and the control groups which served as the pre-test. The students responded to the instruments and it was retrieved, scored and analyzed to ascertain the equivalence of both groups. Teachers in both schools were trained for one week on how to follow the steps and adhere strictly to the different lesson plans. The students in both schools were taught for four weeks. An equivalent form of the pre-test (the items on the instrument were reshuffled) was administered to the students by the teachers as a post-test. The students responded to the instruments and it was retrieved, scored and analyzed.

Research questions were analyzed using descriptive statistics of percentage and mean. Analysis of Covariance (ANCOVA) and Z-test were used to test the null hypotheses at 0.05 level of significance.

Results

Research Question 1: What is the effect of CASTLE (Capacitor-Aided System for Teaching and Learning Electricity) model and Lecture method on the remediation of students' misconception in electric circuit?

Table 1: Mean Scores of Students Taught Electric Circuit using CASTLE Model and those taught using Lecture method for Remediation of Misconceptions.

Groups	n	Pretest		Posttest		Mean Gain (within)
		Mean M_1	S.D	Mean M_2	S.D	
Experimental	85	1.28	1.54	5.47	1.75	**4.19**
Control	71	2.10	1.28	4.07	1.21	**1.97**
Mean gain (between)		**3.38**		**1.40**		**2.22**

Table 1 shows the scores of students whose misconceptions were remediated using CASTLE model and Lecture method. As shown, experimental group had a mean score of 1.28 on the pre-test and a mean score of 5.47 on the post-test. The control group had a mean score of 2.10 on the pre-test and a mean score of 4.07 on the post-test. These mean scores indicate that there was an increase in students' scientific conceptions and a reduction in their misconceptions in electric circuit in both groups after remediation because the experimental group had a mean gain of 4.19 between the pre-test and post-test scores, while the control group had a mean gain of 1.97 between the pre-test and post-test scores. However, the difference between the mean scores (**M_2**) of the experimental and control groups on the post-test 1.40 in favor of the experimental group. This shows that even though the control group had a higher mean score (**M_1**) of 2.10 as against 1.28 for the experimental group in the pre-test,

Research Question 2: What is the effect of CASTLE (Capacitor-Aided System for Teaching and Learning Electricity) model on the remediation of male and female students' misconceptions in electric circuit?

Table 2: Mean Scores of male and female Students Taught Electric Circuit using CASTLE Model for Remediation of Misconceptions.

Groups	n	Pretest		Posttest		Mean Gain (within)
		Mean M_1	S.D	Mean M_2	S.D	
Male	57	1.53	1.54	5.80	1.88	**4.27**
Female	28	0.79	1.28	4.79	1.20	**4.00**
Mean gain (between)		**0.74**		**1.01**		**0.27**

Result in table 2 indicates that the male students had a mean score of 1.53 on the pre-test and a mean score of 5.80 on the post-test. The female students had a mean score of 0.79 on the pre-test and a mean score 4.79 on the post-test. These mean scores indicate that there was an increase in students' scientific conceptions and a reduction in their misconceptions in electric circuit in both groups after remediation. This is because, the male students had a mean gain of 4.27 between the pre-test and post-test scores, while the female students had a mean gain of 4.00 between the pre-test and post-test scores. However, the male students had higher pre-test mean scores of 1.53 as against 0.79 for the female students, which imply that before remediation, the female students had more misconceptions than the male students. The difference between the post-test mean scores (M2) of the male and female students was 1.01 in favour of the male students. This implies that the CASTLE model help in increasing scientific conception and consequent reduction in students' misconceptions in electric circuit amongst the male student than the female students.

H_{01}: There is no significant difference in the mean scores of students whose misconception in electric circuit were remediated using CASTLE model and those remediated using lecture method.

Table 3: **ANCOVA for Effect of CASTLE model and Lecture method on Remediation of Misconception in Electric Circuit.**

Source	Sum of Squares	df	Mean Square	F	P-value.	Partial Eta Squared	Decision
Corrected Model	172.643[a]	2	86.321	50.213	.000	.396	
Intercept	942.308	1	942.308	548.137	.000	.782	
Post-test	96.800	1	96.800	56.308	.000	.269	Rejected
method	122.835	1	122.835	71.453	.000	.318	
Error	263.024	153	1.719				
Total	4080.000	156					
Corrected Total	435.667	155					

Table 3 shows the result of analysis of covariance for the effect of CASTLE model and Lecture method on the reduction in students' misconception in electric circuit. The result indicate $F(1,153) = 71.45$, $P < 0.05$. Based on this, the hypothesis was rejected. This implies that there was a significant difference in the mean scores of students whose misconceptions were remediated using CASTLE model and Lecture method.

H_{02}: There is no significant difference in the mean scores of male and female students whose misconceptions in electric circuit were remediated using CASTLE model.

Table 4: Z-test for Castle Model and Gender

Groups	N	M	S.D.	Z-cal	Z-crit	Decision
Female	28	4.79	1.20	-2.99	1.96	Rejected
Male	57	5.81	1.88			

Result from the Z-test analysis for CASTLE model and gender as shown in table 4 indicates that the null hypothesis that states that there is no significant difference in the mean scores of male and female students on the remediation of misconceptions in electric circuit using CASTLE (Capacitor-Aided System for Teaching and Learning Electricity) model was rejected. This is based on the fact that Zcal value of 2.99 is greater than Zcrt value of 1.96. Hence, there is a significant difference in the mean scores of male and female students on the remediation of misconceptions in electric circuit using CASTLE (Capacitor-Aided System for Teaching and Learning Electricity) model with a better remediation on male students.

Discussion

The findings revealed that there was a reduction in students' misconception and consequently an increase in students' scientific conception in electric circuit amongst students whose misconceptions were remediated using CASTLE model than those remediated using Lecture method. The test of hypotheses also showed that the difference in the mean score of students whose misconceptions were remediated using CASTLE model and those remediated using Lecture method was statistically significance in favor of the CASTLE model group. This significant difference in the remediation could be due to the fact that CASTLE model engages students' interest through hands-on and minds-on investigation, overcome misconceptions that inhibit learning and reasoning, and foster scientific conceptions amongst the students. Conversely, in the lecture method group, the students were mere passive listeners and not engaging in any hands-on activities. This result gave credence to the findings of Wainwright (2019) who carried out a study titled 'Toward Learning and Understanding Electricity: Challenging Persistent Misconceptions'. The study examined the effect of CASTLE model on reduction of students' misconception in electric circuit. The study revealed that CASTLE model had a significant effect on the reduction of students' misconceptions in electric circuit.

Also, in a bid for further investigation, the effect of CASTLE model on male and students' remediation of misconceptions in electric circuit was carried out. The findings revealed that CASTLE model help in increasing scientific conception and consequent reduction in students' misconceptions in electric circuit amongst the male student than the female students. The test of a hypothesis also showed that the difference in the reduction of misconceptions was statistically significant at 0.05 confidence level in favor of the CASTLE model group. This significant difference in the reduction of misconceptions could be attributed to the fact that CASTLE mode of instruction was more of hands-on and activity based approach which required setting up circuits. The male students were more actively involved in the activity than the female students. This could have reflected in their performance.

Conclusion

Based on the empirical evidence presented, the study has shown that CASTLE model is more effective in the remediation of students' misconceptions in electric circuit than the lecture method. The approach affected students' scientific conceptions more positively that the lecture method. The CASTLE model was found to be more effective on the male students' conceptions than the female students due to its activity based, hands-on and minds-on pedagogical approach. The CASTLE model was more effective in challenging students' misconceptions as well as fostering and stimulating students' interest in learning than the traditional method.

Recommendations

The following recommendations are based on the findings of this study.

1. Capacitor-Aided System for Teaching and Learning Electricity (CASTLE) contains instructional materials, homework, and quizzes for challenging common misconception in electric circuit and enhancing conceptual understanding of electricity; governments and school owners should ensure that these materials are be made available to physics teachers and students.
2. Government should avail physics teachers' adequate training on how to effectively use this pedagogical approach in teaching electric circuit.
3. Government and other stakeholders in educational industry should adequately equip the schools laboratories with apparatus such as CASTLE equipment kits for effective teaching of electricity.

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