

Misconceptions in Electric Circuit among Senior Secondary School Physics Students in Rivers State.

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Abstract

This study elicits misconceptions in Electric Circuit among secondary school physics students in Rivers State. The study employed a sequential explanatory mixed method design. The population of the study was 608,789 senior secondary school physics students in co-educational senior secondary schools in Rivers State. A total of 175 SS2 physics students (113 male and 63 female) sampled purposively from two schools participated in the study. Two research questions guided the study. The instrument used in gathering data for the study was a semi-structured interview and a four-tier multiple choice diagnostic test titled “Electric Circuit Diagnostic Four-tier Test”. Test-retest and kuder-Richardson-20 methods of testing reliability were employed to test the reliability of the instrument and reliability coefficients of 0.81 and 0.78 were obtained respectively. The research questions were answered using a thematic analysis on the qualitative data and a descriptive statistics of frequency and percentage were used on the quantitative data. Results from the study revealed that students had high level of misconceptions and lack of knowledge in electric circuit. Among other topics in electric circuit the study revealed that 40.38% of the students had misconceptions in understanding current flow in main branch and parallel branches in an electric circuit which was the highest followed by the topic on identifying short circuit 38%. It was revealed in the study that students exhibited 12 different forms of misconceptions in electric circuit with short circuit model of misconception being the most frequently exhibited form of misconception. Based on the findings of the study, it was recommended among others that the various forms of students’ misconceptions in electric circuit elicited in this study should be taken into consideration by teachers while teaching electric circuit.

Introduction

Learning is a very complex process which varies amongst individuals. 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 (Gaigher, 2014). In the process of attempting to overcome difficulty in understanding, most students usually create ideas 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; Wandersee, Mintzes & Novak, 1994).

Several definitions have been offered to the term "misconception" by different authors. Sanger and Greenbowe (1996) define misconception as student's conceptual and propositional 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 (Soeharto, Csapo, Sarimanah, Dewis & Sabri, 2019). 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, Pappa & Byers, 2019). Generally, efforts by teachers to change students' misconception are usually met with great resistance because they are embedded in the students' cognitive structure (Pesman, & Eryilmaz, 2010). When teachers provide instruction on concept in various subjects they are teaching, more often students already have some pre- instructional knowledge about the topic (Engelhardt, 1997). 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 certain concept is flawed. Most at 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 (Gaigher, 2014).

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, Bayram & Ayas, 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 (Akhilesh, 2014). 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 could result to misconceptions.

Electric circuit is taught in senior secondary two (SS2) physics curriculum in the current 9-3-4 system of education in Nigeria. Studies have shown that electric current is one of the topics that students

have a lot of alternative conception which is not in consonant with scientific conception, due to the abstract nature of the concept of electric current (Pesman, & Eryilmaz, 2010; Soeharto, Sarimanah, Dewi, & Sabri, 2019; Gaigher, 2014). Students know that current flows through a conductor, but seem not to understand how it flows and what is making it flow; it is invisible. This makes students 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 of this concept, students would leave the lesson haven being taught and seemingly understood, but still hold onto their own ideas (alternate conception) about ‘what is really happening’ (Harlen & Qualter, 2014).

Review of studies on diagnosing misconceptions recommended the use of two or more instruments combination to enhance research quality and to make valid interpretation regarding students’ misconception. Such combination is better than a single method (Gurel & Eryilmaz, 2015). Also, Soeharto et al. (2019) in their review of students’ common misconceptions in science and their diagnostic assessment tools in articles published within 2015 to 2019, recommended that performing an integrated combination of instrument can strengthen the method of analysis in obtaining data and eliminating weaknesses found in single instrument. Hence, there is need to combine four-tier diagnostic test and clinical interview in eliciting students’ misconceptions.

Literatures have recommended that four-tier diagnostic test is better among other tools in diagnosing misconceptions in science education (Kaltakci, 2012; Fariyani et al., 2017; Caleon & Subramaniam, 2010). The Four-tier misconception diagnostic test is preferred in this study over other misconception test such as one-tier, two-tier and three-tier test. The four-tier test addresses some weakness 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 justification for combining the four-tier with the interview is because, interviews have problem of generalizability due to small samples, but four-tier test can be administered to a large sample, easily analysed and allows for greater generalizability of findings. Biechner (2016) stated that combining interviews and multiple choice test items seems to be the best way of making sense of students’ understanding when taking the pros and cons of them into account.

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; Heller & Finley, 1992; Shepardson & Moje, 2013). 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 of students’ misconceptions in electric circuit have been reported in international

literatures, most of the studies were conducted outside Nigeria. The misconception 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.

Purpose of the Study.

The purpose of this study is to elicit misconceptions in electric circuit among secondary school physics students in Rivers State. Specifically, the study determined:

1. students' conception of electric circuit.
2. the various forms of misconceptions in electric circuit exhibited by the students.

Research Questions

The following research questions guided the study

1. What are students' conceptions in electric circuit?
2. What are the various forms of misconceptions in electric circuit exhibited by the students?

Methodology

The study adopted a mixed method designs, specifically the Sequential explanatory mixed method design. The research was carried out in two phases. The first phase of the study involved eliciting students' misconceptions using a four-tier diagnostic instrument to collect a quantitative data and the results obtained were probed using a clinical interview approach to obtain a qualitative data. Clinical interviews provide a framework within which students can express their understanding in their own terms, which offers strength to the quantitative data that does not adequately provide details about the context in which the student provides the information (Creswell, 2012). Both the quantitative data and the qualitative data obtained were analysed and interpreted.

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. The choice of only two local governments was to enable the researcher to be able handle the protocols that are involved in carrying out a qualitative and quantitative research in a single study.

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.

Two intact classes were randomly sampled for the study in each school making it a total of four intact classes which consist of 175 students were used for the study. Students identified with multiple misconceptions after their responses to the diagnostic four-tier test were randomly sampled for the Clinical interview for further probing, in-depth inquiry and possibility of elaboration to obtain detail descriptions of students' conceptions.

Data were gathered for the study using two approaches. The qualitative data was obtained using a clinical interview, and quantitative data was obtained using a four-tier diagnostic test instrument. The quantitative instrument was titled "Electric Circuit Diagnostic Four-tier Test" (ECDFT), while the qualitative instrument was a semi-structured interview. 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 weakness 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 interview was used as a follow-up on students identified to have misconceptions from the four-tier test for further probing, in-depth inquiry and possibility of elaboration to obtain detailed descriptions of the students' conception. 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. 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 instruments (ECDFT) were administered to the students with a follow-up semi-structured interview using the clinical approach. This was for further probing, in-depth inquiry and possibility of elaboration to obtain detailed descriptions of the students' conception. The test was scored. The interview was recorded using audio-tape, transcribed by the researcher and a thematic analysis was used to analyse the qualitative data obtained using inductive and deductive approaches. The quantitative and qualitative data obtained were triangulated to determine the students' misconceptions.

The qualitative data obtained from the interview was analyzed using a thematic analysis with an inductive and deductive approach. In these approaches, the audio-taped data was transcribed, data was coded by highlighting the sections of the text that implies alternative conception, themes were generated by identifying patterns among the coded data, themes were defined and named, finally write up the analysis of the data. These set of data were used to flesh out the result obtained from the 'ECDFT' instrument. Research questions were analyzed using descriptive statistics of percentage and mean.

Results

Research Question 1: What are students' conceptions in electric circuit?

Table 1: Summary of Conceptual Identification in the Various Concepts of Electric Circuit

S/N	CONCEPTS TESTED	Frequency and percentages of students' categories of conception										
		Items	SC		LK		FP		FN		MC	
			f	%	f	%	f	%	f	%	f	%
1.	Concept of closed and open circuit	Q1	34	19.43	41	23.43	72	41.14	14	8.00	14	8.00
		Q10	5	2.90	70	40.00	14	8.00	7	4.00	79	45.14
		Total	39	11.14	111	31.71	86	24.57	21	6.00	93	26.57
2.	Understanding current in the main branch and parallel branches in electric circuit.	Q2	33	18.86	68	38.86	4	2.29	10	5.71	60	34.29
		Q6	21	12.00	80	45.71	21	12.00	7	4.00	46	26.29
		Q11	27	15.43	31	17.71	7	4.00	4	2.29	106	60.57
		Total	81	15.43	179	34.10	32	6.10	21	4.00	212	40.38
3.	Understanding Ohm's law.	Q3	17	9.71	75	42.86	21	12.00	7	4.00	55	31.43
		Q5	0	0.00	91	52.00	14	8.00	14	8.00	56	32.00
		Total	27	9.71	166	47.43	35	10.00	21	6.00	111	31.71
4.	Effect of resistors in series on flow of current in a circuit.	Q4	14	8.00	84	48.00	31	17.71	24	13.71	22	12.57
		Q9	17	9.71	66	37.71	14	8.00	17	9.71	61	34.86
		Total	31	8.86	150	42.86	45	12.86	41	11.71	83	23.71
5.	Effect of resistors in parallel on flow of current in a circuit.	Q7	20	11.43	71	40.57	11	6.29	8	4.57	65	37.14
		Total	20	11.43	71	40.57	11	6.29	8	4.57	65	37.14
6.	Identifying short circuit.	Q8	14	8.00	61	34.86	15	8.57	9	5.14	76	44.43
		Q12	15	8.57	68	38.8	10	5.71	25	14.29	57	32.57
		Total	29	8.29	129	36.86	25	7.14	34	9.71	133	38.00

SC: Scientific Conception; LK: Lack of Knowledge; MC: Misconception; FP: False Positive; FN: False Negative

Result from table 1 revealed that students had five categories of conceptions namely: Scientific Conception (SC), Lack of Knowledge (LK), False Positive (FP), False Negative (FN) and Misconception (MC). These were exhibited in different percentages across the six concepts in electric circuit upon which the students were tested namely: closed and open circuit, understanding current in main and parallel branches in electric circuit, understanding Ohm's law, effect of resistors in series on the flow of current in electric circuit, effect of resistors in parallel on the flow of current in electric circuit and identifying short circuit. Results from table 4.1 revealed that on Concept of closed and open circuit, 26.56% of the students had misconception, while 11.14% had scientific conceptions, 31.71% lacked knowledge, 24.57% had false positive and 6.00% had false negative conception.

Upon testing their understanding of current in the main branch and parallel branches in electric circuit, 40.38% of students had misconceptions, 15.43% had scientific conception, 34.10% lacked knowledge, 6.10% had false positive and 4.00% false negative. Upon testing their understanding of Ohm's law, 31.71% of the students had misconception, 9.71% had scientific conception, 47.43% lacked knowledge, 10.00% false positive, and 6.00% false negative. In ascertaining their understanding of the effect of resistors in series on flow of current in an electric circuit, it was revealed that 23.71% of the students had misconceptions, 8.86% had scientific conception, 42.86% lacked knowledge about the concept, 12.86% false positive and 11.71% false negative. In finding out their understanding of effect of resistors in parallel on flow of current in an electric circuit, apparent that 31.43% of the students had misconceptions, 27.43% had scientific conception, 34.86% lacked knowledge about the concept, 4.00% false positive and 2.29% false negative. Upon testing the students' ability in identifying short circuit, it was revealed that 38.00% of the students had misconceptions, 8.29% had scientific conception, 36.86% lacked knowledge about the concept, 7.14% false positive and 9.71% false negative.

Research Question 2: What are the various forms of misconceptions in electric circuit exhibited by the students?

Table 2: Frequency and Percentage of Occurrence of the Various Forms of Misconceptions Elicited from the Students across the Test Items.

S/N	Types of Misconceptions	Frequency	Percentage
1.	Sink model	32	4.59
2.	Attenuation model	44	6.31
3.	Shared current model	45	6.46
4.	Clashing current model	35	5.02
5.	Empirical model	56	8.04
6.	Short circuit model	133	19.08
7.	Battery as a constant source of current	81	11.62
8.	Parallel circuit model	77	11.05
9.	Sequential reasoning	59	8.46
10.	Local reasoning	63	9.04
11.	Current flow as water flow	72	10.33
	TOTAL	697	100

Results from table 2 revealed the various forms of misconceptions in electric circuit and its frequencies and percentages with which they were exhibited by the students. It was revealed that the students under investigation had 12 different forms of misconceptions namely: Sink model, attenuation model, shared current model, clashing current model, empirical model, short circuit model, power as a constant source of current, parallel circuit model, sequential reasoning, local reasoning, current flow as water flow. It was shown that amongst the various forms of misconception exhibited by the students, 19.08% of the misconceptions were short circuit model of misconception which ranked the highest amongst other types of misconceptions exhibited by the students. This was followed by “battery as a constant source of current” and parallel circuit model of misconceptions with 11.62% and 11.05% respectively. The sink model of misconception had the least occurrence amongst the various model of misconception exhibited by the students with 4.59%. The study also revealed that students tend to have multiple misconceptions in electric circuit.

In a bid for further probing, in-depth inquiry and possibility of elaboration to obtain detailed descriptions of the students’ conception in electric circuit, interviews were conducted with two groups of students. One group consists of 7 SS2 Students from school A, and the second group consists of 7 SS2 students from school B. The misconceptions detected during the interviews are presented in sequence of some significant episodes from the interviews. Here are few of the excerpts from the episodes.

Sink model

Some electric circuit diagrams on a piece of paper were shown to the interviewees. Below is one of the excerpts from the transcribed interview with the students from which the sink model of misconception was revealed.

Researcher R: From the diagram shown to you on this paper, do you think that connecting a piece of wire from a terminal of a battery to a device (bulb) would power the device?

Interviewee I_a: *Yes the bulb will light.*

R: why do you think it will light?

I_a: *Since there is a contact between the device and the battery, it will make it light.*

R: How about connecting another wire to the other terminal of the battery?

I_a: *well, I don't know, but I think this one you showed me will light.*

R: Ok

From the interview, students believed that when the wire is connected to the top of the battery, the bulb in the circuit will light. Students failed to understand that the loop has to be closed to ensure flow of charges in the circuit. Students also lack the understanding of the configuration of the bulb as to know if the wire has to be connected to the thread-like path of the bulb and the base of the bulb has to connect to the battery to ensure that the circuit is closed to trigger the flow of charges (current). Students are of the view that current leaves the battery via the piece of wire and goes straight to light up the bulb without another wire been connected to the other terminal of the battery. This implies that students believe that single wire connection from the terminal of a battery allows electricity to sink power to the device (bulb) thereby powering the device.

Clashing current model

Here is an episode from the interview with one of the students

R:Do you have an idea of how a bulb as shown in the diagram light up and what probably makes it light?

I_k: *You mean how a bulb to light?*

R: Yes, and what makes it light up

I_k:*mmh, the bulb has to be connected to a battery.*

R: How do you mean?

I_k: *I think the bulb has to be connected with a wire to the battery. You will connect the wire to the positive and negative and point of the battery and current will move from the positive and the negative sides and the bulb will light.*

R: How do you mean current will move from the positive and negative sides and the bulb will light?

I_k: *Ok, what I mean is that the current from the positive and negative sides of the battery will move through the wire cause a spark or light in the bulb.*

R: So you mean both current meet up somewhere in the bulb and that will cause the bulb to light?

I_k: *Yes.*

R: Alright

From this excerpt, it is obvious that the student believe that positive electric charges emanate from the positive terminal of the battery and negative charges moves from the negative terminal of the battery, meets up and clashes in the device (bulb). The resultant effect from the clash is the light from the bulb. This student is of the view that the cause of the light in the bulb is as a result of the opposing currents moving from both terminals of the battery. This response from the student depicts the clashing current model that is evident in literature.

Superposition reasoning

This particular form of misconception was not diagnosed using the four-tier diagnostic test, but it was revealed in the interview with the students. Here is an excerpt from one of the interviews with the students that depicts superposition reasoning model of misconception in electric circuit.

R: Take a look at these sets of circuit as shown in this diagram. Can you compare the brightness of the bulbs in both circuits?

I_d: The bulb in the second circuit will be brighter

R: Why do you think so?

I_d: You can see that the second circuit has two batteries, while the first circuit has only one battery, so I think the circuit with more batteries will produce more current to make the bulb in that circuit brighter than the bulb in the first circuit that has only one battery.

R: Ok.

From the responses of the interviewee, it was evident that this student had a superposition reasoning which is also a model of misconception in electric circuit. Analyses of these responses revealed that students think that if one battery makes a bulb shine, then two or more batteries will make the bulb shine twice as bright, regardless of the configuration or arrangement of the battery.

Discussion

The study revealed the students had a high percentage of lack of knowledge across the six concepts of electric circuit on which they were tested. This could be as a result of improper pedagogical approaches to teaching electric circuit concept and student's lack of confidence in their responses to the test items. Also, it was unravelled in the study that students had a high percentage of misconceptions across the concepts. This result could be attributed their faulty prior knowledge, improper interpretation of experiences in electricity, improper presentation of concepts by the teachers, erroneous explanation of scientific concepts in some textbooks and improper use of analogies to explain certain scientific concepts. These were justified and evidence in the interview sections the researcher had with the students in the cause of probing their conceptual understanding of electric circuit. The students were making references to the explanations and analogies giving to them by their teachers. Some were making mention of some analogies and diagram in some textbooks to give a justification to their answers. This result corroborate the findings of Setyani et al. (2017) who carried out a study to investigate students' conception and perception of simple electric circuit in University Sebalas Maret, Surakarta in Indonesia. The study revealed that a high proportion of students lack knowledge of electric circuit and exhibit a high percentage of misconceptions; and that these misconceptions were influenced by their perceptions and supposed by their experiences and improper use of scientific language; although, other forms of misconception elicited in this study were not evident in their study.

Result from the study also give credence to the findings of Widodo et al (2018) who carried out a study on unravelling students' multiple misconceptions on electric circuit on 60 students (prospective science teachers) at one of the state universities in Indonesia. The study revealed that most of the students had multiple misconceptions. The result of this study also support the findings of Kapartzianis and Kriek (2014) who carried out a study to examine the use of conceptual change activities in alleviating students' misconception about electric circuit in a technical school of Limassol in Cyprus.

Results from the interviews revealed the common misconceptions held by students, which were similar to the misconceptions elicited using four-tier diagnostic test. Although, another form of misconception (superposition reasoning) which was not diagnosed using the four-tier diagnostic test was revealed during the interview sections with the students. The various forms of misconceptions diagnosed were not different from the misconceptions reported in literature. This result could also be attributed to their faulty prior knowledge, improper interpretation of experiences in electricity, improper presentation of concepts by the teachers, erroneous explanation of scientific concepts in some textbooks and improper use of analogies to explain certain scientific concepts. These were justified and evidence in the interview sections in the cause of probing their conceptual understanding of electric circuit. The students were making references to the explanations and analogies giving to

them by their teachers. Some were making mention of some analogies and diagram in some textbooks to give a justification to their answers. This result is in consonance with the findings of Pesman & Eryilmaz (2010) who carried out a study on the development of a Three-tier test to assess misconceptions about simple Electric Circuit on 124 ninth-grade students in Ankara, Turkey. The study revealed that students exhibited 11 different forms of alternative conceptions in electric circuit which includes: Sink model, attenuation model, shared current model, clashing current model, empirical model, short circuit model, power as a constant source of current, parallel circuit model, sequential reasoning, local reasoning, and current flow as water flow.

Conclusion

Based on the empirical evidence presented, the study has shown that students had five different categories of conceptions in electric circuit namely; Scientific conception, Lack of knowledge, False positive, False negative and misconception which were in different proportions across the various topics on electric circuit. Also, students lack knowledge in electric circuit and exhibited high level of misconceptions in identifying short circuit and understanding current flow in the main branch and parallel branches in an electric circuit.

The students exhibited 12 different forms of misconception on electric circuit namely; Sink model, attenuation model, shared current model, clashing current model, empirical model, short circuit model, power as a constant source of current, parallel circuit model, sequential reasoning, local reasoning, current flow as water flow and superposition reasoning.

Recommendations

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

1. The various forms of students' misconceptions in electric circuit elicited in this study should be taken into consideration by teachers while teaching electric circuit.
2. Teachers should come up with a better pedagogical approach that would enhance proper understanding of short circuit and concept of current flow in the main branch and parallel branches in an electric circuit since students tend to exhibit high level of misconceptions in this concepts.
3. Teachers and textbook authors should be mindful of the analogies they use in illustrating scientific concepts so that it wouldn't entrench misconceptions amongst students.
4. Teachers should always elicit students' faulty prior knowledge and improper interpretation of experiences in abstract science concepts like electricity before or while teaching the students.

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