Effectiveness of Learning Cycle in Exploring Students' Preconceptions on Selected Concepts in Direct Current Electricity

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ABSTRACT

The study was conducted to investigate the effectiveness of learning cycle teaching approach in promoting understanding and exploring students' preconceptions on selected concepts in direct current electricity. Fifty-nine (n = 59) students from one intact form three (3) science class was conveniently selected from the six senior secondary schools offering the General Science Programme in the New Juaben Municipality to participate in the study. The main instruments used for data collection were Current Electricity Concept Achievement Test (CECAT) which comprised of 30 multiple choice items and Students' Learning Cycle Activity Sheets. The t-test for dependent samples, thematic content analysis and percentages were used to analyze the data collected. Findings showed that the learning cycle approach promotes students' understanding of concepts in direct current electricity and also very effective for exposing students' preconceptions.

Key Words: Alternative conception, conceptions, Misconceptions, Learning cycle, Preconceptions.

INTRODUCTION

Research on students' prior conceptions and their role in teaching and learning science has become one of the most important domains of science education for the past 30 years (Duit & Treagust, 2003). Preconceptions are conceptions of students before they are exposed to formal instruction (Berg, 2001). Students' preconceptions are either consistent with the scientist's view or contradict the scientifically correct views. The contradicting ideas are sometimes known as 'alternative conceptions', 'misconceptions', 'children science', 'naïve theories' and 'conceptual misunderstanding' (Küçüközer & Demirci, 2008). The reasons why students' hold alternative conceptions could be attributed to a plethora of factors: teaching methods, mismatch between science concepts and students' cognitive development levels, gender, insufficient connection between concepts or between pre-existing knowledge and new ones, textbook information, absenteeism of students, informal learning which takes place outside the classroom and many others (Aubrecht & Raduta, 2005; İpek & Çalık, 2008; Türkmen & Usta, 2007). Everyday language, culture and religion can also lead to the formation of alternative conceptions (Tytler, 2002).

Without knowing about students' existing understanding of concepts in science, the private theories they hold, and the influence of their alternative thinking on their understanding of concepts in science, how can science teachers teach effectively and meaningfully? With this in mind, teachers have to find out how students think about certain phenomena before deciding on the particular experience and theory to present in their science classes. The analysis of students' pre-existing knowledge always provides useful data about students' understanding of concepts (Chiu, Guo & Treagust, 2007).

Students at different stages hold one of the following preconceptions about simple electric circuit prior to formal instruction of which some contradict the right scientific concepts (Ipek & Çalık, 2008): (a) Unipolar model/sink theory; (b) Clashing Current theory/two-component model (c) Closed circuit model; (d) Current consumption model/Attenuation model; (e) Constant current source model; (f) Scientific view. Other preconceptions include the use of the concepts current and voltage interchangeably (Engelhardt & Beichner, 2004). If one battery makes a bulb shine with a certain brightness, then two batteries would make the bulb shine twice as bright regardless of the configuration (Sebastia, 1993). Current divides into two equal parts at every junction regardless of what is happening elsewhere (Rhöneck & Grob, 1987).

The basic question asked often is which of the teaching strategies is very effective for eliciting students' preconceptions and promoting understanding of concepts in science? The learning cycle approach is one of the constructivist's teaching methods which increases the likelihood that students are engaged in the type of thinking that constructivists argue is necessary for productive thinking (Lawson, 2001). The learning cycle approach can result in greater achievement in science, better retention of concepts, improved attitudes toward science and science learning, improved reasoning ability, and superior process skills than would be the case with the traditional instructional methods (Hanuscin & Lee, 2007; Yilmaz & Cavas, 2006). The three-phase learning cycle method (exploration, term introduction and concept application phases) according Türkmen (2006) should be reinforced throughout the science curriculum and should also be used in context at every level of education since it helps teachers to explore the entry behaviour of students and at the end of the lesson, teachers are able to quantify what students have achieved. However, very few researches have been conducted using learning cycle to explore students' preconceptions on concepts in direct current electricity.

The study therefore investigated the effectiveness of the learning cycle approach in promoting understanding and exploring senior High school students' preconceptions on selected concepts in direct current electricity. The study sought answers to the following questions:

1. To what extent can the learning cycle approach promote senior high school students' understanding of selected concepts in direct current electricity?
2. How effective are the learning cycle activities in exploring students' preconceptions on selected concepts in direct current electricity?

METHODOLOGY

A pre-experimental design which contains one-group pretest-posttest was used in this study. One intact form three (3) science class was conveniently selected from the six senior secondary schools offering the General Science Programme in the New Juaben Municipality to participate in the study. Fifty-nine (n =59) students took part in the study. Students took a pretest to measure their prior knowledge of the selected concepts in direct current electricity followed by teaching of the selected concepts by the researcher and a posttest after the intervention to determine students' academic achievements. Students were given activity sheet at the beginning of each activity for students to make predictions and give explanations to their responses before performing the activity. This exposed students' preconceptions and in all nine activities were performed in the study.

INSTRUMENTATION

The study employed both quantitative and qualitative procedures of data collection. Quantitative data was gathered using a concept understanding test called Current Electricity Concept Achievement Test (CECAT) for both pretest and posttest. CECAT was developed by the researcher and consisted of thirty (30) multiple choice test items. In developing CECAT, a set of instructional objectives were constructed after consulting the senior secondary school syllabus and textbooks for information on the subtopics treated under direct current electricity. The reliability of CECAT after pilot testing was calculated using KR-20 and was found 0.76. The validity of the test was checked by two experienced physics teachers and two physics lecturers in the Department of Science and Mathematics Education. The discrimination and difficulty indices of the test were also determined and found to be adequate. Qualitative data was gathered from students' learning cycle activity sheets.

DATA ANALYSIS AND RESULTS

The pretest and posttest scores for the group were compared using the t-test for dependent samples. As shown in Table 1, there is a statistically significant difference between the groups' pretest and posttest scores.

Table 1:

Results of Dependent Samples t-test for the Pretest and Posttest Scores for the Group

Groups	Tests	N	Mean	SD	t	df	p
Group	Pretest	59	10.54	2.575	-21.177	58	0.001*
	Posttest	59	21.14	2.240			

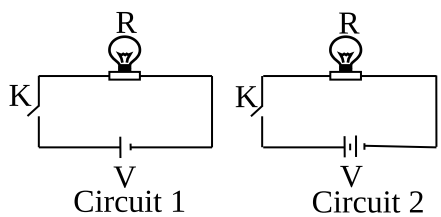
*Significant, since $p < 0.05$

The group's mean score from posttest (M = 21.14, SD = 2.240) was significantly higher than the mean score from the pretest (M = 10.54, SD = 2.575, t (59) = -21.177, p = 0.001). This implies that the learning cycle approach is effective for promoting understanding.

To determine students' preconceptions in the selected concepts in direct current electricity, thematic content analysis technique was used to analyze students' responses and reasons given on the students' learning cycle activity sheets.

Students' Learning Cycle Activity 1

Predict what you expect about the brightness of bulb R if one more identical dry cell is added to circuit 1 as shown in circuit 2 [the bulbs are identical]. Explain your response.



In this activity, the correct prediction is that the brightness of the bulb will increase because the source voltage has been doubled. From Table 2, all the 50 students rightly predicted that there will be an increase in brightness with 47 (94%) of the students giving the correct reason.

Table 2:

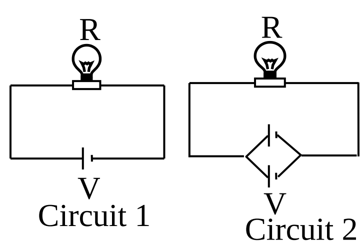
Students' Preconceptions about the Brightness of a Bulb in a Circuit, when Identical Dry Cells are connected in Series (n = 50)

Students' predictions and reasons	Number of students	%
Brightness will increase	50	100
1. There are two cells in circuit 2 which doubles the voltage.	47	94
2. More current will be supplied by the two cells than one cell.	3	6

Again, 3 (6%) students gave a correct reason that more current will be supplied by the two cells than one. They may be using Ohm's law to give their reasons. This means that their preconceptions are in line with the scientists views.

Students' Learning Cycle Activity 2

Predict what you expect about the brightness of bulb R if one more identical dry cell is added to circuit 1 as shown in circuit 2 [the bulbs are identical]. Explain your response.



In this activity, the correct prediction is that the brightness of the bulb will remain the same because when identical dry cells are connected in parallel, their effective voltage is equal to the voltage of one of the dry cells. Since the cells are ideal (i.e. having no internal resistance), each cell will contribute half of its voltage to produce the total voltage in the circuit. As shown in Table 3, 21 (36.8%) students predicted correctly that the brightness of the bulb will remain the same.

However, 9 (15.8%) students out of the total students were able to give the correct reason that each of the dry cells will contribute half of its voltage to produce the total voltage in the circuit; 4 (7.1%) students gave an incorrect explanation that the voltage produced by the dry cells is the same as the circuit voltage; whereas 8 (14.1%) students could not explain their predictions.

From Table 3, 31 (54. 4%) students predicted wrongly that the brightness of the bulb will increase with 16 (28.1%) students giving the reason that the voltage in the circuit will be doubled, 7 (12.3%) students reasoned that the current produced by the cells will be added together and 8 (14.1) students gave no reasons for their predictions. Furthermore, 5 (8.8%) students predicted wrongly that the brightness of the bulb will decrease but did not explain their reasoning.

It implies therefore that 16% of the students have the right conception about the brightness of a bulb when identical dry cells are connected in parallel whiles 84% of them have alternative conceptions on the concept.

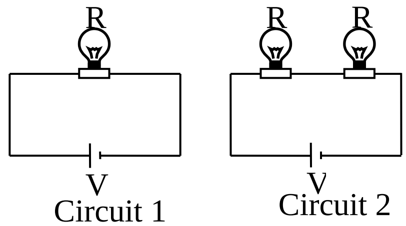
Table 3:

Students' Preconceptions about the Brightness of Bulb in a Circuit, when Identical Dry Cells are connected in Parallel (n = 57)

Students' predictions and reasons	Number of students	%
Brightness will increase	31	54.4
1. The voltage in the circuit will be doubled.	16	28.1
2. The current produced by the cells will be added together.	7	12.3
3. No explanation.	8	4.1
Brightness will decrease	5	8.8
1. No explanation	5	8.8
Brightness will remain the same	21	36.8
1. The voltage produced by the dry cells is the same as the circuit voltage.	4	7.1
Each of the dry cells will contribute half of its voltage to produce the total voltage in the circuit.	9	15.8
3. No explanation.	8	14.1

Students' Learning Cycle Activity 3

Predict what you expect about the brightness of bulb R if one more identical bulb is added to circuit 1 as shown in circuit 2 [the dry cells are identical]. Explain your response.



In this activity, the correct prediction is that the brightness of the bulbs will decrease because the source voltage will be shared equally among the identical bulbs. From Table 4, 46 (78%) students predicted correctly that the brightness of the bulbs will decrease out of which 13 (22.1%) students gave the correct scientific explanation; 12 (20.3%) students also reasoned correctly that when one more identical bulb is added to the circuit the resistance will increase thereby reducing current flow; 18 (30.5%) students on the other hand, gave an incorrect explanation that the current will be shared among the bulbs. This category of students used current instead of voltage which means they use both words interchangeably. Finally, 3 (5.1%) students gave no explanation for their prediction.

As shown in Table 4, 7 (11.9%) students predicted wrongly that the brightness of the bulbs will increase with 3 (5.1%) students giving the reason that it is because the bulbs are connected in series; whereas 4 (6.8%) students gave no explanation for their reasoning. Again, 6 (10.2%) students predicted wrongly that the brightness of the bulbs will remain the same with 4 (6.8%) students giving the reason that the voltage is constant in the circuit whiles 2 (3.4%) students gave no explanation for their predictions.

This means that 42% of the students have the correct conception about the brightness of bulbs connected in series to a dry cell in a circuit whiles 58% of them have alternative conceptions of the concept.

Table 4:
Students' Preconceptions about the Brightness of Identical Bulbs connected in Series to a Dry Cell (n = 59)

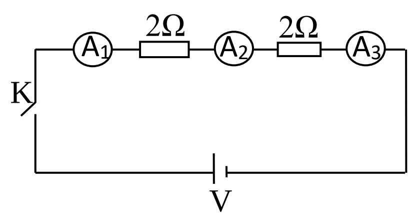
Students' predictions and reasons	Number of students	%
Brightness will increase	7	11.9
1. The bulbs are in series.	3	5.1
2. No explanation.	4	6.8
Brightness will decrease	46	78
1. The current will be shared among the bulbs.	18	30.5
2. The resistance of the circuit will increase.	12	20.3
3. The voltage of the cell will be shared among the bulbs.	13	22.1
4. No explanation.	3	5.1
Brightness will remain the same	6	10.2
1. The voltage is constant in the circuit.	4	6.8
2. The current is the same in the circuit.	2	3.4

Students' Learning Cycle Activity 4

Suppose ammeter A_1 shows a reading of 0.06A. Choose from the alternatives below the correct answer for the current measurements of ammeter A_2 and ammeter A_3.

A. A_2 = 0.05A A_3 = 0.04A.
B. A_2 = 0.06A A_3 = 0.05A.
C. A_2 =0.06A A_3 = 0.06A.
D. A_2 = 0.07A A_3 = 0.08A

Explain your response.



In this activity, the correct option is C because current is constant throughout the main circuit in series connection (i.e. current is not consumed by circuit elements). As shown in Table 5, 28 (47.5%) students predicted correctly and chose option C with 23 (34%) students giving the correct reason that the current is the same in the main circuit in every series connection.

Table 5:

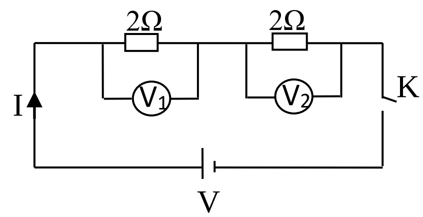
Students' Preconceptions about the Conservation of Current in a Series Circuit (n = 59)

Students' predictions and reasons	Number of students	%
Option A	25	42.4
1. The resistors will use up the current in the circuit.	18	30.5
2. No explanation.	7	11.9
Option B	2	3.4
1. The resistors use up the current	2	3.4
Option C	28	47.5
1. The current is the same the main circuit in every series connection	23	34
2. No explanation.	5	8.5
Option D	4	6.8
1. No explanation		

On the other hand, 5 (8.5%) students gave no reasons for their prediction. From Table 5, 25 (42.4%) students chose the wrong option A with 18 (30.5%) of the students giving the reason that the resistors will use up the current in the circuit; 7 (11.9%) students gave no explanations for choosing the option. Furthermore, 2 (3.4%) students chose option B giving the reason that the resistors use up the current. As shown in Table 5, 4 (6.8%) students chose option D but gave no explanations for the choice. From Table 5, 34% of the students have the right conception that current is not consumed by circuit elements. However, 66% of the students have alternative conceptions on the concept out of which 34% reasoned that current is consumed by circuit elements.

Students' Learning Cycle Activity 5

Will the reading on voltmeter V_1 be the same or different from the reading on voltmeter V_2? Explain your response.



In this activity, the correct prediction is that the readings of the voltmeters will be the same because the source voltage will be shared equally among the resistors in the circuit. As shown in Table 6, 43 (72.9%) students predicted correctly that the voltmeters will have the same readings. Out of this, 13 (22.1%) students gave the correct scientific explanation; 11 (18.6%) students gave an incorrect reason that current is directly proportional to the potential difference; 4 (6.8%) students reasoned incorrectly that voltage is constant in a series circuit; whereas 15 (25.4%) students gave no explanation for their prediction. From Table 6, 15 (25.4%) students predicted wrongly that the voltmeters will have different readings. Out of this, 6 (10.2%) students gave the reason that the resistors will decrease the voltage in the circuit, 1 (1.7%) student reasoned that the current flow in the circuit will not be the same and 8 (13.6%) students gave no explanation for their prediction.

It implies that 22% of the students have the correct conception about the voltage across resistors connected in series in a circuit whiles the rest 78% have alternative conceptions about the concept.

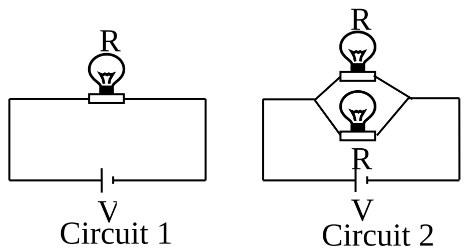
Table 6:

Students' Preconceptions about the Potential Difference across Identical Resistors connected in Series (n = 59)

Students' predictions and reasons	Number of students	%
Same readings	43	72.9
1. Current is directly proportional to the potential difference.	11	18.6
2. The voltage is shared equally across similar resistors.	13	22.1
3. The voltage is constant in a series circuit.	4	6. 8
4. No explanation	15	25.4
Different readings	15	25.4
1. The resistors will decrease the voltage in the circuit.	6	10.2
2. The current flow is not the same in the circuit.	1	1.7
3. No explanation.	8	13.6

Students' Learning Cycle Activity 6

Predict what you expect about the brightness of bulb R if one more identical bulb is added to circuit 1 as shown in circuit 2 [the dry cells are identical]. Explain your response.



In this activity, the correct prediction is that the brightness of the bulbs will remain the same because the voltage across bulbs connected in parallel are the same. As shown in Table 7, 38 (65.5%) students predicted correctly that the brightness of the bulbs will remain the same. Out of this, 15 (25.9%) students gave the scientifically correct explanation that voltage across bulbs connected in parallel are the same; 14 (24.1%) students gave the incorrect explanation that the same current will flow through the two bulbs; whereas 8 (13.8%) students gave no reasons for their prediction.

Table 7:

Students' Preconceptions about the Brightness of Identical Bulbs connected in Parallel to a Dry Cell (n = 58)

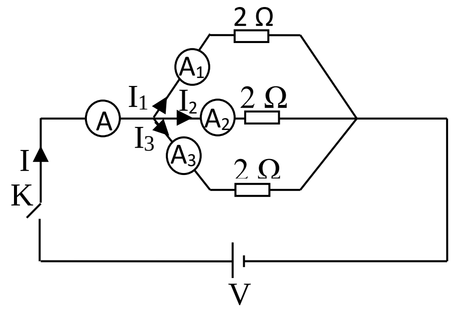
Students' predictions and reasons	Number of students	%
Brightness will decrease	20	34.5
1. The current is shared among the bulbs in the circuit.	5	8.6
2. The voltage is shared among the bulbs in the circuit.	7	12.1
3. No explanation.	8	13.8
Brightness remain the same	38	65.5
1. The voltage across bulbs connected in parallel are the same.	15	25.9
2. The same current flows through the two bulbs.	14	24.1
3. No explanation.	8	13.8

Twenty-four point five (34.5%) students predicted wrongly that the brightness of the bulbs will decrease with 5 (8.6%) students giving the reason that current is shared among the bulbs in the circuit, 7 (12.1%) students gave the reason that voltage is shared among the bulbs in the circuit and 8 (13.8%) students gave no explanations for their prediction.

This means that 26% of the students have the correct conception about the brightness of bulbs connected in parallel whiles 74% of them have alternative conceptions about the brightness of the bulbs.

Students' Learning Cycle Activity 7

Will the readings on ammeters A, A_1, A_2 and A_3 be the same or the ammeters will have different readings? Explain your response.



In this activity, the correct prediction is that the readings on the ammeters will be different because the current through ammeter A will be shared among the branches of the circuits containing ammeters A_1, A_2 and A_3 (i.e. $A = A_1 + A_2 + A_3$). At the junction, the current I will be divided equally among the three 2Ω resistor (i.e. $I_1 = I_2 = I_3$). From Table 8, 34 (58.6%) students predicted correctly that the readings will remain different. Out of this, 18 (31.1%) students gave the correct scientific explanation that the current through A will be shared among A_1, A_2 and A_3; 6 (10.3%) students gave an incomplete explanation that the resistors are connected in parallel; whereas 10 (17.2%) students gave no explanations for their prediction. From Table 8, 24 (41.4%) students made an incorrect prediction that the readings will be the same. Out of this, 3 (5.2%) students gave the reason that the circuit has the same 2Ω resistors; 8 (13.8%) students reasoned that the same current flows through the circuit; 2 (3.4%) students gave the reason that the resistors are arranged in parallel; whereas 11 (19%) students gave no explanations for their prediction.

It means therefore that 31% of the students have the correct scientific conception that the ammeter readings are different whiles 69% have alternate conceptions about the concept.

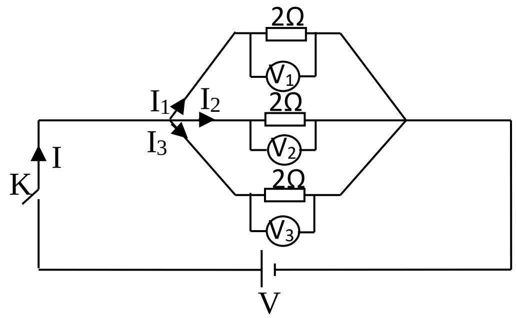
Table 8:

Students' Preconceptions about Current Flow in A Circuit when Identical Resistors are connected in Parallel (n = 58)

Students' predictions and reasons	Number of students	%
Same readings	24	41.4
1. The circuit has the same 2Ω resistors.	3	5.2
2. The same current flows through the circuit.	8	13.8
3. The resistors are arranged in parallel.	2	3.4
4. No explanation.	11	19
Different readings	34	58.6
1. The current through A will be shared among A_1, A_2 and A_3.	18	31.1
2. The resistors are connected in parallel.	6	10.3
3. No explanation.	10	17.2

Students' Learning Cycle Activity 8

Will the reading on voltmeter V_1, V_2, and V_3 be the same or the voltmeters will have different readings? Explain your response.



In the activity, the correct prediction is that the readings of the voltmeters will be the same because the voltage across a parallel connection of resistors is constant. From Table 9, 41 (70.9%) students predicted correctly that the readings on the voltmeters will be the same.

Table 9:

Students' Preconceptions about Voltage across Identical Resistors connected in Parallel in a Circuit (n = 58)

Students' predictions and reasons	Number of students	%
Same readings	41	70.9
1. The voltage across a parallel circuit is constant.	24	41.4
2. No explanation.	17	29.3
Different readings	17	29.3
1. The voltage is shared among the resistors.	9	15.5
2. No explanation.	8	13.8

Out of this, 24 (41.4%) students gave the correct explanation that the voltage across a parallel circuit is the same with 17 (29.3%) giving no explanations for their prediction. From Table 9, 17 (29.3%) students predicted wrongly that the readings of the voltmeters will be different with 9 (15.5%) giving the reason that the voltage is shared among the resistors and 8 (13.8%) students giving no explanations for their prediction.

It means that 41% of the students have correct conception about voltage across identical resistors connected in parallel in a circuit while 59% of them have alternative conceptions about the concept.

DISCUSSION

In summary, the results showed that the use of the learning cycle approach was successful and promotes students' understanding of concepts in direct current electricity. This finding is consistent with the view that correct use of the learning cycle accomplishes effective learning of science concepts (Lawson, 2001; Ates, 2005, Yilmaz & Cavas, 2006).

The results from students' learning cycle activity sheets on various tasks revealed the following preconceptions of students about selected concepts in direct current electricity: All the students have the correct conception that the brightness of a bulb will increase when identical dry cells are connected in series in a circuit, giving the reason that the voltage will be doubled to supply more current; 16% of the students have the right conception about the brightness of a bulb when dry cells connected in parallel giving the reason that the brightness will remain the same since each dry cell will contribute half of its voltage whiles 84% of them have alternative conceptions on the concept; 42% of the students have the correct conception about the brightness of bulbs connected in series to a dry cell in a circuit by predicting that the brightness of the bulbs will decrease giving the reason that the source voltage will be shared among the bulbs while 58% of them have alternative conceptions of the concept; 34% of the students have the right conception that current is not consumed by circuit elements (resistors) in a series circuit while 66% of the students have alternative conceptions on the concept; 22% of the students have the correct conception that the source voltage will be shared equally among similar resistors connected in series in a circuit while 78% have alternative conceptions about the concept; 26% of the students have the correct conception about the brightness of bulbs connected in parallel predicting that the brightness will remain the same giving the reason that voltage across bulbs connected in parallel are the same while 74% of them have alternative conceptions about the concept; 31% of the students have the correct scientific conception that the ammeter readings are different with the reason that the current through ammeter A will be shared among ammeters A_1, A_2 and A_3 (i.e. $A = A_1 + A_2 + A_3$) while 69% have alternate conceptions about the concept; and 41% of the students have correct conception about voltage across identical resistors connected in parallel in a circuit giving the reason that voltage across a parallel circuit is constant while 59% of them have alternative conceptions about the concept.

The most common alternative conceptions identified among the students are as follows: The brightness of a bulb connected in series to dry cells connected in parallel will increase because the voltage of the cells will increase; the brightness of bulbs connected in series will decrease because the current will be shared among the bulbs; current is consumed or used up by circuit elements or resistors; voltage is constant in a series circuit; the brightness of bulbs connected in parallel to a dry cell will decrease because the source voltage is shared among the bulbs in the circuit; The voltage is shared equally among resistors connected in parallel in a circuit; and resistance decreases the voltage in a circuit. These findings support some of the findings of İpek and Çalık (2008); Sebastia (1993) and Engelhardt and Beichner (2004) who are of the view that students hold alternative conceptions about some concepts in direct current electricity.

CONCLUSION

The learning cycle approach promotes students’ understanding of concepts in direct current electricity and also very effective in exposing students’ preconceptions.

IMPLICATIONS FOR EDUCATIONAL PRACTICE

The learning cycle approach which uses inquiry based activities should be encouraged in many physics instructions, since it offers students more opportunities to explore, discuss, challenge and test their pre-existing ideas about concepts before formal instruction. Teachers should as much as possible try to learn and use the learning cycle approach in their instructions since it exposes students’ correct and alternative conception about concepts in science prior to instruction.

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