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Bukidnon Secondary Physics Teachers' Alternative Views and Associated Mental Models on Simple DC Circuits

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ABSTRACT

The purpose of this study was to determine secondary physics teachers' conceptions about Simple DC circuits. Data were obtained from responses in two sets of concept tests related to DC circuits and Determining and Interpreting Resistive Electric Circuits Concept Test (DIRECT) developed by Engelhardt and Beichner. The study involved 24 physics teachers teaching in private and public high schools in Bukidnon. Results have shown that teachers have misconceptions similar to those held by students. Moreover, the study was extended to determine the usefulness of workshop activities on the same subject matter in identifying and improving the alternative views and associated mental models that the teachers hold.

Keywords: *DC Circuits, alternative conceptions, mental models*

INTRODUCTION

Most students rely on their teacher's knowledge. Consequently, students' conceptual understanding of a subject could either improve or get worse depending on what alternative conceptions their teacher have on the same subject. In order to address this problem with teachers' conceptions, trainings and workshops have been conducted to ensure teachers' competency but giving more attention on their level of performance rather than confronting their alternative conceptions. Studies would show that most students hold misconceptions very similar to those of their teachers (Bilal and Erol, 2009). Trainings may have raised the teacher's level of confidence, yet there remain the manifestations of the failure to bring out clarity of their students' understanding closely linked with their own.

Investigations on students and teachers' misconceptions on mechanics have been widely studied. A number of studies have also been conducted to identify students' misconception with electricity and magnetism as area of concentration, such as students' misconceptions on electric current (Duit et al., 1985; Shipstone et al., 1988; Fleer, 1994; Borges and Gilbert, 1999; Shepardson & Moje, 1999), potential difference and current (Millar and Beh, 1993; Millar & King, 1993); electric circuits (Andre and Ding, 1991); electric diagrams (Johsua & Dupin, 1985); current and energy (Arnold and Millar, 1987) as indicated in the study by Mahapatra (2004). Mahapatra reported that misconceptions among students are similar regardless of their previous educational background and that difficulties persist even after instructions in the subject matter.

There are only few researches investigating teachers' understanding of electricity and magnetism. Electricity is a common science topic and it is relevant to everyday life. People have become so dependent on electricity in almost everything, yet it has also caught the ire of many as number one cause of fires and have taken the lives of people either accidentally or on purpose. The relevance of understanding circuits is seen in its usefulness in our daily life activities, in our safety whether at home, in school, in the office, and even while on travel. This study investigated secondary physics teachers alternative views of DC Circuits and the associated mental models employed.

Knowledge of teachers' alternative views can offer valuable information in identifying the possible models they adopted. Moreover, understanding teachers' diverse views is an important consideration in creating or reinventing an innovative teaching approach for more conceptual understanding among their students.

The information generated from this study can provide teachers with a way of evaluating their own progress and conceptual difficulties which their students may also have to bear. A teacher with misconceptions could mislead the class and would miss to bring out clarity to students' conceptual understanding. On the other hand, a teacher with conceptions similar to those of the experts or acceptable to the physics community, are more able to see clearly what learning their students are going through.

This study aimed to determine Bukidnon secondary physics teachers' conceptions and the associated models related to DC Circuits that they employ. Specifically, this research investigated the teachers' alternative conceptions on simple DC circuit, examined the mental models used to analyze electric circuits, and at the same time, determined the effectiveness of an approach in obtaining conceptual clarity related to simple DC circuits.

METHODOLOGY

The target population of this study consisted of Bukidnon secondary physics teachers. Considering the availability of teachers and the budget and time constraints of the researcher, convenience sampling was employed to obtain the total of thirty respondents. Fifteen of the respondents were chosen from the private schools and another fifteen from the public schools in Bukidnon. To remove bias, respondents teaching physics with different majors (physics, general science, math and other fields) from both clusters were tapped. Some teachers who took the pretest failed to join the workshop thus, data were obtained from twenty-four respondents only who completed all the activities.

To determine the teachers' concepts of simple DC circuits, the test Determining and Interpreting Resistive Electric Circuits Concept Test (DIRECT) developed by Engelhardt and Beichner (2004) was employed. It was first tested for reliability by several secondary and college physics teachers from different provinces such as Bohol, Caraga and Davao. Due to its high reliability of 0.81, this researcher decided to use it for this study for comparison with results done by researchers abroad.

A Module on Simple DC circuits by Mahapatra was adapted along with questions for the activities to be done. It was first tried for trustworthiness among graduate science students with a reliability of 0.75

Permission to conduct research was first sought from the Schools Division Superintendents. The physics teachers from selected private and public schools were informed, consulted and given orientation about the activities that this research shall entail.

The DIRECT was given to selected teachers in their respective location as pretest to expose teachers' conceptions on DC circuits. Respondents were enjoined to attend a workshop on DC circuits. The workshop was conducted on a non-working day to allow the teachers to come to CMU. Each participating teacher was given a breadboard and copy of the module and physics manual as reference. Before the workshop, teachers were made to respond to questions related to simple circuits, the same questions found in the modules developed by Mahapatra. Following the modules, the participants made out the circuits using the breadboard. The set of questions were again answered as teachers followed the module. At the end of the activity, DIRECT was again given as posttest. The teachers who participated in the workshop were visited at least a month after the workshop to conduct the interview on questions related to the modules.

RESULTS AND DISCUSSION

The teachers' conceptions of DC circuits were explored from the pretest on DIRECT. Table 1 shows Bukidnon teachers' pretest in DIRECT with a mean of 9.125 or 31%. Table 2 presents answers which reveals that Bukidnon teachers have poorer grasp of almost all concepts. In particular, their greatest difficulty was in identifying a complete circuit and in applying the concept of power in a variety of circuits. Similar difficulties were also found among CMU engineering students in a research study made by Taganahan, Bucayong and Tabudlong (2010- unpublished).

Table 1

t-test Results for Pretest for Teachers taking DIRECT and those from US as Reported by Engelhardt and Beichner

	Mean	Standard Deviation	Degrees of Freedom	t	p value
Pretest of Bukidnon Teachers	9.125	3.276	23	13.652	.000
US students	14	3.4	600	8.5	.000

The low result in Objectives 1-5 of DIRECT may indicate that teachers do not have a clear understanding of the underlying mechanisms of electric circuits. This is shown in their difficulty identifying a closed circuit and shorts within circuits or deficiency of knowledge on contacts for light bulbs. According to Engelhardt and Beichner, one source of difficulty is confusion of terms. While the teachers in this study did fairly in applying the conservation of energy, most of them exhibited very weak understanding of power when shown a variety of circuits. There is tendency to think that current is the cause of voltage, battery as a source of current and that when resistances are equal, current would also be the same. They have difficulty connecting their knowledge about the microscopic aspects of current flow with electrostatic terms such as electric potential differences and resistance.

Table 2
Objectives for DIRECT and Pretest-Posttest Results

Objective	Item Numbers	Mean% Pretest	Mean% US	Mean% Irish
Physical aspects of DC electric circuits (Objectives 1-5)		**27**	**56**	**47**
1. Identify and explain short circuit	10, 19, 27	21	56	48
2. Understand the functional two-endedness of circuit elements	9, 18	39	54	56
3. Identify a complete circuit(Objective 1-3 combined)	27	14	68	52
4. Apply the concept of resistance	5, 14, 23	18	59	39
5. Interpret pictures and diagrams of a variety of circuits	4, 13, 22	35	55	45
Energy (Objectives 6-7)		**33**	**42**	**35**
6. Apply the concept of power to a variety of circuits	2, 12	7	37	38
7. Apply a conceptual understanding of conservation of energy	3, 21	59	47	33
Current (Objectives 8-9)		**33**	**44**	**24**
8. understand and apply conservation of current	8, 17	45	62	33
9. Explain the microscopic aspects of current flow	1, 11, 20	24	31	16
Potential difference (voltage) (Objectives 10-11)		**41**	**46**	**50**
10. current is influenced by potential difference and resistance	7, 16, 25 6, 15, 24, 28	41	60	72
11. Apply the concept of potential difference to a variety of circuits	29	37	37	28

The teachers were made to answer two sets of test on DC Circuits before the actual performance of the activities. Table 3 presents the teachers' responses in the two sets of test which are shown by categories. The average score obtained in Set I is 4.3 and for Set II is 2.7 while in the study by Mahapatra (2009), the average score for Set I is 4.4 and Set II is 3.3. The results recorded by categories may identify slight differences. Most Bukidnon teachers answered all questions in Set I correctly but half of those who gave correct answers either could not grade the bulb or cannot give a valid explanation. The remaining 33% could not answer all questions correctly while in Mahapatra's 46% of the teachers could not answer all questions, could not grade the bulb and explanations were incorrect. In Set II, 63% of Bukidnon teachers could not answer the questions nor grade the bulb and explanations were incorrect.

Table 3

Percentage of Teachers in Different Categories of Responses in the Pretest

Objective	% of Response	
	Set I	Set II
Could answer all the questions correctly, grade the bulb correctly and correct explanation given.	33(23)	12(19)
Could answer all the questions correctly but could not grade the bulb with explanation given supporting their reasoning.	25(23)	8(15)
Could answer all the questions correctly and grade the bulb correctly but no explanation given.	8(8)	17(12)
Could not answer all the questions correctly. Could not grade the bulb and gave incorrect explanation	33(46)	63(54)

Teacher responses in Two Sets of Test on DC Circuits by Categories

The result of DIRECT revealed that teachers have not clearly understood the concepts related to DC circuits. What models did they employ to give such responses? Tables 4a and 4b show the analysis of explanations that reveal teachers' alternative conceptions which helped identify the models associated with such thinking as shown in the transcript of selected answers with associated explanations in Set I and Set II.

Most teachers reasoned that bulbs placed nearer the source is brighter. This alternative conception uses the model "current consumption model". According to Karrqvist, 1985; Borges & Gilbert, 1999 as quoted by Mahapatra, the current consumption model is the belief that current flows from positive to negative plate of cell. Hence, the bulb nearest the source shall have more current. Another common misconception is that they consider bulbs as ohmic resistors or one having linear resistance which employs the "Universality of Ohm's Law model". According to Metioui et al, 1996 as quoted by Mahapatra, the universality of Ohm's law considers ohmic resistance to remain the same irrespective of the value of V or I. It should be remembered that Ohm's law has its limits and that bulbs are not linear resistances.

Table 4a

Transcript of Selected Answers with Associated Explanations, Set I

No.	Question	Answer	Explanation/(Model)
1a	Bulb A is brighter than bulb B	YES	Because bulb B is connected in series with bulb C (correct)
		YES	Because bulb B shared the voltage with C which voltage is solely used by A (correct)
		YES	Because bulb A is the first connected (incorrect) **(Model: Current consumption model)**
		YES	Because electrons can focus only in one bulb in A unlike in B (ambiguous)
		YES	Because the voltage passed through bulb A has not been separated (ambiguous)
		NO	Because the flow of current in A is slowly decreasing (incorrect)
		YES/NO	No explanation
1b	Bulb B is brighter than bulb C	NO	Because bulbs are identical and they are connected in series (incomplete)
		NO	Because bulb is connected to positive and ends in negative (ambiguous) **(Model: Unipolar model)**
		NO	Because bulbs B and C have equal voltage drop (incorrect) **(Model: Universality of Ohm's Law)**
		NO	Because the same current flows to both bulbs (incomplete)
		YES	Because B receives more current than C (incorrect) **(Model: Current consumption model)**
		NO	Because according to Ohm's law in series current are equal and voltage shared equally (incorrect- incomplete) **(Model: Universality of Ohm's Law)**
		YES/NO	No justification
1c	Bulb D is brighter than bulb E	NO	Because the bulb are in parallel (correct, incomplete)
		NO	Because bulb D and E have the same source (ambiguous)
		NO	Because they have the same energy supplied (correct)
		NO	Because the distribution of electricity in parallel circuit is equal (ambiguous) **(Model: Constant current Model)**
		YES/NO	No explanation
1d	Bulb B is brighter than bulb C Bulb F is brighter than bulb G	YES	Because bulb F receives more current than bulb G (correct-incomplete)
		NO	Because even if current is divided among loads in parallel, bulbs are identical (incorrect, ambiguous) **(Model: Universality of Ohm's Law)**
		YES	Because bulb G has the energy shared with bulb H (correct)
		YES	Because it's a parallel-series connection (incomplete)
		YES	Because the electrons flowing the second wire can be divided by the two bulbs (incorrect) **(Model: Current consumption model)**
		YES	Bulb F is brighter than G because electricity follows another circuit (ambiguous)
		YES	Because bulb G will be using half of emf than bulb F (incorrect)
1e	Bulb G is brighter than bulb H	NO	Because both bulbs use the same energy (correct)
		YES	Because the bulbs have equal resistance (incorrect) **(Model: Universality of Ohm's Law)**
		NO	Because for the same battery, bulbs in series the electrons that flow are the same (incorrect) **(Model: Constant current source model)**
		NO	Because both bulbs have the same emf (incorrect)
		YES	Because G will use ample energy and allows only the remaining energy through bulb H (incorrect) **(Model: Closed circuit model)**
		YES	Because bulb G is the first bulb to have the flow of electrons (incorrect) **(Model: Current consumption model)**

Table 4b

Transcript of Selected Answers with Associated Explanations, Set II

No.	Question	Answer	Explanation/(Model)
2a	Brightness of the bulb A and B will be the same in all the diagrams	NO YES NO NO NO	The bulbs will not have the same brightness because set-up of cells differ. Flow of electrons should be from positive to negative terminal.(incorrect, ambiguous) **(Model: Unipolar Model)** Bulbs have the same brightness except for Fig C because cells are connected in opposing directions so voltage is zero (correct) Because the positions of the cells vary so does the brightness of bulbs will be affected (incorrect) **(Model: Current consumption model)** In Fig C bulb is not as bright because cells are in opposite polarity(correct) Because the connections are not the same (incorrect)
2b	Brightness of the bulb B_1 and B_2 are not equal	NO NO NO NO NO YES YES/NO	In Fig C bulb is not as bright because cells are in opposite polarity(correct) Because the connections are not the same (incorrect) Because both circuits are the same (correct, incomplete) Because distance of the bulbs affects their brightness(incorrect) **(Model: Current consumption model)** Because the circuits are the same, voltage are the same and bulbs are in series (correct) Because the dry cells are connected in different manner(incorrect) No justification
2c	Brightness of the bulb B_2 and B_4 are not equal	NO NO YES YES YES/NO	Because B4 is indirectly connected in two sources while B2 is not (ambiguous) Because both bulbs in series have equal emfs Because there is more current in B2 than in B4 (incorrect, ambiguous) **(Model: Closed circuit model)** Because the location of the dry cells are different though they are parallel with each other (incorrect) No explanation
2d	Bulb B_4 is brighter than B_3	YES NO NO NO YES/NO	Because B3will not light up due to opposing polarity of the cells (correct) Because B3will not light up at all (correct, incomplete) Because source have the same voltage and bulbs are identical (incomplete) Because bulbs are connected in series (ambiguous) No justification
2e	Bulb B_4 is brighter than B in set I	YES NO YES YES YES/NO	Because the source of B4 has greater potential or voltage (correct) Because B in set I has to share energy with another bulb, while B4 does not (incomplete) Because in set I, bulb B has only one voltage source (incorrect) Because the number of cells affects the brightness of bulb (correct, incomplete) No justification

Other common misconceptions of the teachers are: 1) Current in the bulbs in series are always the same regardless of how many are connected to the battery. This alternative conception is due to the “Constant current model” (Cohen et al, 1983 as mentioned by Mahapatra); 2) Current must be from positive to negative terminals of bulbs uses the “Unipolar model” (Osborne, 1981) which considers the flow of current from positive terminal of battery to the base of the bulb where it is all used up. It must be remembered that bulbs do not have positive nor negative terminals and can be connected to the battery in any way; 3) When current passes a circuit element, only then will it use and liberate energy. This conception is due to the “Closed circuit model.” According to Karrqvist, 1985, as quoted by Ates, 2005, the "Closed circuit model" considers that circuit elements have two connections. Current circulates around circuit in a given direction and current flow through a resistive circuit element where energy is liberated.

Table 5 reveals that there was a significant difference in the scores of the Posttest (6.0, SD=1.1) as compared to with the Pretest (MD=4.3, SD=1.1) in Module 1, and Posttest (4.3, SD=1.4) as compared to with the Pretest (MD=2.7, SD=1.7) in Module 2. However Scores in DIRECT Posttest (10.3, SD=3.7) as compared to with the Pretest (MD=9.1, SD=3.3) was found not significant.

Table 6 presents a comparison of the Pretest and Posttest using t-test. It shows test yielded a t(23)=5.948 for Set I and t(23)=5.751 for Set II. It can be safely concluded that the change was brought about by the hands-on activity. Thus the modules used in the workshop are deemed effective. While teachers did better in the Posttest for DIRECT, with a mean of 10.2917±3.6651 as compared to the Pretest mean of 9.125±3.27457, the normal gain is only 5.87%.

Table 5

Means of Pretest and Posttest on DC test from modules and Pretest & Posttest of DIRECT

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	PostSet I	6.0000	24	1.10335	.22522
	Pre Set I	4.3333	24	1.12932	.23052
Pair 2	PostSet II	4.2917	24	1.42887	.29167
	PreSet II	2.7083	24	1.70623	.34828
Pair 3	DIRECTPost	10.2917	24	3.66510	.74814
	DIRECTPre	9.1250	24	3.27457	.66842

Although DIRECT Posttest-Pretest difference is not significant, it was still able to determine the alternative conceptions that teachers held.

Table 6
t-test for Pretest-Posttest of DC Circuits Set I and Set II and DIRECT

		Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Pair 1	POSTSet I PRESet I	1.6667	1.37261	.28018	1.0871	2.2463	5.948	23	.000
Pair 2	POSTSet II PRESet II	1.5833	1.34864	.27529	1.0139	2.1528	5.751	23	.000
Pair 3	DIRECTPost DIRECTPre	1.1667	3.43469	.70110	-.2837	2.6170	1.664	23	.110

Table 7 reveals a further analysis of teachers' responses to the DC tests in the modules by categories. The table also shows how teachers have improved in these categories. All teachers were able to answer all questions in Set I with an increase in 30% as shown by their ability to grade the bulbs and give correct explanations. While there were still teachers who could not answer nor give correct explanations for questions in Set II, the number of those who were able to answer correctly doubled. The number of those who answered correctly, grade the bulbs with correct explanations increased by 75% (12% to 21%); the number of those who can answer all the questions correctly but could not grade the bulb with explanation supporting their reasoning increased by 212% (8%-25%); while the number of those can answer all the questions correctly and grade the bulb correctly but no explanation increased by more than 124% (from 17% to 38 %).

Table 7
Percentage of Teachers in Different Categories of in Pretest-Posttest Compared

Categories	% of Response			
	Set I		Set II	
	Pre	Post	Pre	Post
Could answer all the questions correctly, grade the bulb correctly and correct explanation given.	33	63	12	21
Could answer all the questions correctly but could not grade the bulb with explanation given supporting their reasoning.	25	29	8	25
Could answer all the questions correctly and grade the bulb correctly but no explanation given.	8	8	17	38
Could not answer all the questions correctly. Could not grade the bulb and gave incorrect explanation	33	0	63	16

CONCLUSION

This study revealed that Bukidnon teachers hold conceptions of DC circuits far from being scientific or acceptable. They have difficulties identifying a closed circuit and shorts within circuits and even with bulb contacts to make them light up. It is indicative that they do not have a clear understanding of the underlying mechanisms of electric circuits. Confusion on the use of terminologies was also seen in their responses confusing current with voltage or power, voltage for energy.

Some of the alternative conceptions Bukidnon physics teachers have are: (1) The brightness of a bulb differs with its distance from the source, bulbs placed nearer the source is brighter; (2) Bulbs are ohmic resistors or one that have linear resistance; (3) Current in the bulbs remain the same regardless of how many bulbs are in series because current is constant; (4) As current moves from positive terminal of battery to the bulbs at the bottom part; (5) Bulbs liberate energy as current is passed through it. The underlying causes of these misconceptions are due to the mental models that teachers use as gleaned from their explanations. Accordingly, this study showed the following mental models teachers use: "Current consumption model"; Universality of Ohm's Law model"; "Constant current model", "Unipolar model" and 'Closed circuit model".

A workshop on hands-on activities related to DC circuits was effective in changing teachers' way of reasoning and improving their understanding of the concepts. Teachers had the opportunity of comparing their predictions from their observations and check their understanding of concepts on DC circuits.

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