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Alternative Conception about Open and Short Circuit Concepts

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Abstract

The goal of this work-in-progress is to evaluate and analyze alternative conceptions among students about an open and short circuit concepts. This study was carried out in Kuala Lumpur, Malaysia and involved first-year electrical engineering students. In order to find out what these alternative conceptions were, students' pre- and post-test answers to three questions on concept test were analyzed. The results show that students held very strong alternative conceptions on the concept tested. Their interviewed data were analyzed to investigate about their understanding. The result will be useful in determining the teaching and learning activities that could help rectify their alternative conceptions.
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1. Introduction

Students' alternative conception has been in the study of many research where investigation into students' interpretation of concepts both before and after going through a particular subject (Ogunfunmi and Rahman 2010; Prince, Vigeant et al. 2010; Smaill, Rowe et al. 2011). Alternative conceptions about electric circuit have been widely investigated in physics (McDermott 1996; Engelhardt and Beichner 2004), and also in electrical engineering (Streveler, Geist et al. 2006; Ogunfunmi and Rahman 2010; Smaill, Rowe et al. 2011). Streveler and her teams have found that students who are academically successful often lack deep understanding of fundamental concepts in their study (Streveler, Geist et al. 2006). They also found that it is common for lecturers to overestimate the degree to which students understand concepts.

This study indulges in work by (Streveler, Litzinger et al. 2008; Ogunfunmi and Rahman 2010; Smaill, Rowe et al. 2011) in investigating about conceptual understanding of Electrical Engineering students. Learning conceptual knowledge in engineering science is a critical element in the development of competence and expertise in engineering (Streveler, Litzinger et al. 2008). Based on works done by (Streveler, Geist et al. 2006) in identifying difficult concepts in Electric Circuits that has produced a list ranking of 27 items of important and difficult concepts for students to learn. This study is taking Thevenin and Norton theorem as the main topic to be investigated on students' learning difficulties. Based on preliminary studies, students are found to bear misunderstanding in solving circuit to get the resistance for both theorems (Hussain, Latiff et al. 2009). The underlying concepts in determining

the resistances for Thevenin and Norton theorem are open and short circuit concepts (Irwin 2002; Boylestad 2004; Dorf and Svoboda 2004). Therefore this study will investigate the alternative conception held by students in handling open and short circuit concept.

2. Description of the Research

The study is carried out in Malaysia and involved first-year electrical engineering students. The course under consideration for this research is basic electric circuit course. Electric Circuit, DDE 1103 is offered to all students enrolls in Diploma in Electrical Engineering. One group of 47 students was the participants of this study. This study was conducted during their second semester where they have learnt Electric Circuit from their first semester.

Investigations about students' alternative conceptions were gathered through concept test and interviews. One concept was adapted from (Sabah 2007) which was based from (Engelhardt 1997; Engelhardt and Beichner 2004). The concept test containing 12 questions on the basic concepts of open and short circuit and was used for pre- and post-test. The circuit with a switch was manipulated to introduce the condition of open and short.

The interview was conducted in groups of three to four students as there as more comfortable of talking rather than alone. The intervention was given during the second semester. Discussion about the intervention will be discussed in the next paper to be published.

For the purpose of this paper, only three questions will be discussed and analyzed. Students were interviewed where they had to explain about questions that they had answered wrongly. The format of three questions as presented to the students can be found in the Appendix.

3. Results

Students' answers in the pre- and post-test were tabulated in the tables. The shaded shows the correct answer. The marks obtained from pre- and post-test were analyzed with SPSS using paired-sample t-test. The data obtained from interview were analyzed qualitatively to find students' alternative conceptions on open and short circuit. The interview data is quoted based on coding as R for researcher and S for students. The effect size is calculated using Cohen *d* (Cohen 1992).

3.1. Simple Circuit

Question 6 required students to consider the operation of the circuit after the switch is opened. Table 1 shows the data obtained from students answer.

6. After the switch is opened, what happens to the resistance of resistor R?

a. Increases.

b. Stay the same.

c. Goes to zero.
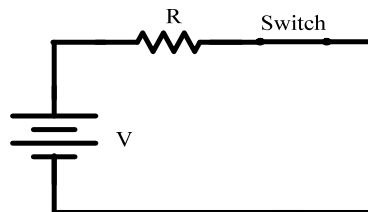
Reason:

a.   The value of resistance depends on the applied voltage.

b.   Since there is no current, the resistance of the resistor will go to zero.

c.   The electrical resistance does not depend on current or voltage.

d.   Since there is no current, the resistance of the resistor will increase.

e.   Others (Please specify): _____

Table 1. Students' answer to Question 6

	Answer & Reason	% Pre-Test Response	% Post-Test Response
% Students' Answer & Reasons	BC	48.9	85.1
	CB	29.8	6.4
Concept Tested in Q6	Switch will define which elements active or inactive in a circuit.		
Analysis of Response	This circuit asked for resistance during an open circuit. Students' answer shows that the held high alternative conceptions about resistance in an open circuit.		

The data showed that 48.9% responded correctly (answer B and reason C) for pre-test, and increased to 85.1% in the post-test. However students (29.8% in pre-test and 6.4% in post-test) who answered C *(goes to zero)* and reasoned B *(since there is no current, the resistance of the resistor will go to zero)*, relied heavily on Ohm's law, where they assumed current as the prime concept. This conclusion was made based on interview data as quoted below.

> **R:**   *When there is no current, what happen to R?*
> **S9:**   *Hmmm we have to use V=IR?*
> **R:**   *Ok…if you think you have to.*
> **S9:**   *If there is no current, and we want to find the value of R, so R is 0 isn't? Because there is no current.*
>
> **R:**   *When the switch is opened, is there any current flow?*
> **S1:**   *No*
> **R:**   *If no current, is there any voltage?*
> **S1:**   *No, since cannot use ohms law.*
>
> **R:**   *When the switch is opened, is there any resistance value?*
> **S5:**   *I think when the switch is opened, no current flow, therefore the resistance is also zero.*

Data from paired-sample t-test is shown in Table 2 and Table 3.

Table 2. Paired-sample statistics to Question 6

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Q6_post	1.7872	47	.62332	.09092
	Q6_pre	1.0213	47	.94384	.13767

Table 3 Paired-samples t-test to Question 6

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Q6_post - Q6_pre	.76596	1.23733	.18048	.40266	1.12925	4.244	46	.000

From Table 2 and Table 3, there was a statistically significant increased in the scores for Question 6 from pre-test (M=1.02, SD=0.94) to post-test (M=1.79, SD=0.62), t(47)=4.24, ρ<.0005 (two-tailed). The mean increased in scores was 0.77 with a 95% confidence interval ranging from lower bound of 0.40 to an upper bound of 1.13. The effect size of Cohen *d* is 0.97 was large.

3.2. Short Circuit

Question 8 required students to consider the operation of the circuit after the switch is closed. Table 4 shows the data obtained from students answer.

8.   What is the total resistance of the circuit when the switch is closed?

    a.   50 Ω

    b.   10 Ω

    c.   8 Ω

    d.   0 Ω
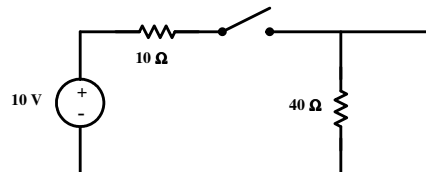
Reason:

    a.   The total resistance is the sum of the two resistors.

    b.   Only the 10 Ω resistor operates in the circuit.

    c.   The two resistors are in parallel.

    d.   Because the total resistance equals zero in a closed circuit.

    e.   Others (Please specify): _____

Table 4. Students' answer to Question 8

	Answer & Reason	% Pre-Test Response	% Post-Test Response
% Students' Answer & Reasons	BB	72.3	85.1
	AA	19.1	8.5
Concept Tested in Q8	Switch will define which elements active or inactive.		
Analysis of Response	A circuit with switch and short circuit. Varieties of alternative conception showed by students.		

The data showed that 72.3% responded correctly (answer B and reason B) for pre-test, and increased to 85.1% in the post-test. However students (19.1% in pre-test and 8.5% in post-test) who answered A *(50Ω)* and reasoned A *(the total resistance is the sum of the two resistors)*, ignored the effect of the short circuit. This conclusion was made based on interview data.

> **R:** *What happen to current when it reaches the two branches?*
> **S12:** *Divided into two branches because the branch is in parallel.*
>
> **R:** *What happened to the current flow at the node?*
> **S14:** *Flow into both branches.*

Data from paired-sample t-test is shown in Table 5 and Table 6.

Table 5. Paired-sample statistics to Question 8

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Q8_post	1.7660	47	.66636	.09720
	Q8_pre	1.4043	47	.90071	.13138

Table 6. Paired-samples t-test to Question 8

|		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Q8_post - Q8_pre	.36170	1.05141	.15336	.05300	.67041	2.358	46	.023

From Table 5 and Table 6, there was a statistically significant increase in the scores for Question 8 from pre-test (M=1.40, SD=0.90) to post-test (M=1.77, SD=0.67), $t(47)=4.24$, $\rho<.0005$ (two-tailed). The mean increase in scores was 0.36 with a 95% confidence interval ranging from lower bound of 0.05 to an upper bound of 0.67. The effect size of Cohen *d* is 0.47 was moderate.

3.3. Open Circuit

Question 10 required students to consider the operation of the circuit when the switch stayed open. Table 7 shows the data obtained from students answer.

10   What is the voltage between points A and B?

    a.   0 V

    b.   12 V

    c.   Less than 12 V
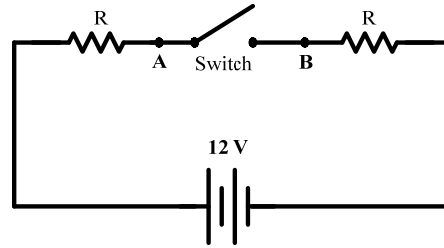
Reason:

    a.   There is no voltage since there is no current flowing.

    b.   Because some of the voltage of a battery has dropped across the resistors.

    c.   If there is no resistance, there will be no voltage dropped.

    d.   Others (Please specify): _____

Table 7. Students' answer to Question 10

	Answer & Reason	% Pre-Test Response	% Post-Test Response
	BD		4.3
% Students' Answer & Reasons	AA	55.3	40.4
	AC	10.6	19.1
	CB	17.0	23.4
Concept Tested in Q10	Voltage persists, but current does not, in an open circuit.		
Analysis of Response	The question asked for open circuit voltage. Varieties of answer were given which shows student held many alternative conceptions about open circuit voltage.		

The data showed that only 4.3% responded correctly (answer B and reason D) for post-test. There are three responses that was wrongly answered and reasoned by students. They responded wrongly (answer A and reason A) (55.3% in pre-test and 40.4% in post-test); (answer C and reason B) (17.0% in pre-test and 23.4% in post-test); (answer A and reason C) (10.6% in pre-test and 19.1% in post-test). All the wrong answers given really showed their alternative conceptions were held by them where they cannot notice the effect of open circuit on voltage and also on resistance as proved in Question 6. The conclusion can again be made that students relied heavily on Ohm's law, where they assumed current as the prime concept. This conclusion was made based on interview data as quoted below.

> ***R:*** *Can you explain to me about this question?*
> ***S14:*** *Now the switch is open, no current flow, therefore no voltage at A-B.*
>
> ***R:*** *Why 0 Volt at A-B?*
> ***S3:*** *Because of open circuit.*
> ***R:*** *Is there any voltage drop at each resistor?*
> ***S3:*** *No, because of no current.*

> ***R:*** *Is there any voltage at A-B?*
> ***S4:*** *No. How come got any voltage if there is no current?*
>
> ***R:*** *Can you explain your answer and reason?*
> ***S10:*** *There is no voltage since there is no current flowing.*
>
> ***R:*** *Can you explain?*
> ***S12:*** *My answer is A, because when there is no current, the voltage also zero.*

Data from paired-sample t-test is shown in Table 8 and Table 9.

Table 8. Paired-sample statistics to Question 10

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Q10_post	.1489	47	.41592	.06067
	Q10_pre	.0638	47	.24709	.03604

Table 9. Paired-samples t-test to Question 10

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Q10_post - Q10_pre	.08511	.50346	.07344	-.06271	.23293	1.159	46	.252

From Table 8 and Table 9, there was not statistically significant increase in the scores for Question 10 from pre-test (M=0.06, SD=0.25) to post-test (M=1.15, SD=0.42), t(47)=4.24, $\rho<.0005$ (two-tailed). The mean increase in scores was 0.09 with a 95% confidence interval ranging from lower bound of 0.06 to an upper bound of 0.23. The effect size of Cohen *d* is 0.26 was small.

4. Conclusion

The answers given by university students to the concept test and interviews were studied with the aim of evaluating and analyzing alternative conceptions in students understanding of an open and short circuit concepts in basic electric circuit course. The most striking result is when student has alternative conception of "when there is no current; there is also no voltage and therefore no resistance." These conceptions defined that they relied heavily on Ohm's law where they are considering current as the prime concept. However the paired-sample t-test results showed that student has improved significantly in simple circuit; improved moderately in short circuit; but very small improvement on open circuit. Having characterized these alternative conceptions, further work should be carried out into determining teaching and learning activities (Streveler, Litzinger et al. 2008) that could help rectify their alternative conceptions especially on open and short circuit concepts. Student-centred teaching and learning should be emphasized as these methods could help student actively participate in overcoming their own alternative conceptions (Kearney 2004). Also it would be a good idea to take advantage of new interactive technologies in mind with the aim of teaching millennial students (Taylor and MacNeil 2005).

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