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Constructing a Two-Tier Test about Source Current to Diagnose Pre-Service Elementary School Teacher' Misconceptions

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Abstract—We discuss the alternative conceptions of students analysing the behaviour of electrical circuits. The present paper aims at, on one hand, studying the misconceptions of 80 elementary pre-service teachers from Quebec in Canada, in relation to the current source in DC circuits. To do this, they completed a two-choice questionnaire (true or false) with justification. Data analysis identifies many conceptual difficulties. For example, their majority considered a battery as a source of constant current: When a circuit composed of battery and resistors is modified, the current supplied by the battery remains unchanged. On the other hand, considering the alternatives conceptions identified we develop a two-tier test about source current. The aim of this two-tier test is to help teachers to diagnose rapidly their students' misconceptions in order to consider in their teaching.

Keywords**—**Two-tier diagnostic test, current source, pre-service teachers, alternative conceptions after teaching, qualitative study.

I. Introduction

SINCE the advent of Piaget theory, much research has been done about students' conceptions about physical phenomena, such as heat and temperature, light, force and movement, gravity, electricity and electrostatic phenomena. Most of these conceptions have been identified as erroneous relatively to scientific conceptions [1]. In the area of basic circuit theory, central theme of the present study, works conducted with students from the secondary school to the university, show that most conceptual difficulties stem from a gap in the representations of the concepts of current and voltage [2]-[11]. The erroneous models highlighted in this research are: (1) the unipolar model: currents flows from the battery to the bulb; (2) the clashing currents model: currents flowing towards the light bulb from each battery terminal collide and produce the observed phenomenon; (3) the attenuation model: currents leaves the battery from one end, is partly dissipated in the bulb, its unused portion returning to the battery; (4) the sharing model: each of several components receive and consume identical currents; and (5) the sequential model whereby a modification of component can affect current only downstream. In a synthesis study on the sequential model, Shipstone [9] stated: "The importance of this misconceptions (sequential model) is due both to its high incidence in the middle years of secondary school and to its persistence among able students who have specialized in physics: it was found, for example, in seven out of eighteen graduate physicists and engineers who were training to be physics teachers." (p.305) Furthermore, the concept of voltage seems to present serious conceptual difficulties as most students explicitly or implicitly equate it with electrical current. For that, some research develops constructivist sequences relating to the teaching of electrical circuits and helps the student to understand the concepts of current and voltage [12]. However, despite a significant contribution from this research, they are not used by most teachers [12], [13]. Several factors come into play, such as the training of teachers in didactics, the constraints of the curriculum and the textbooks used, which do not consider the conceptual difficulties of the students, widely diffused in the review of the international literature. In order to overcome some of these difficulties, more and more researchers are developing two-tier and three-tier diagnostic tests to elicit secondary and high school students' misconceptions about electrical circuits [14], [15], optics [16], mechanics [17], [18], photosynthesis [19], heat, temperature and internal energy [20], thermal physics [21], static electricity [22], electrochemical cells [23], [24]. Note that these developments allow teachers to obtain quick information on the conceptual understanding of their students before and after teaching.

There are few two-tier conceptual tests on topics in electrical circuits, so in this study, we developed a conceptual; survey covering the distribution of the current in simple circuits, called Electrical Diagnostic Test (EDT).

II. Purpose of Research

This research has two objectives; firstly, we manage a questionnaire to identify the elementary pre-service teachers' alternative conceptions regarding the electrical current source in DC circuits after teaching. Secondly, we develop a two-tier Electrical Current Source Diagnostic Test.

A. Pre-Service Teachers' Alternative Conception

1. Description of the Population

80 students (aged 19 to 23) participated in this study and they are registered in the third year of university in the Baccalaureate Program in Elementary Pre-service Teachers which is of a length of four years. These students came from the sector of human sciences and they all studied during their secondary education as part of general physics course some notions linked up with electrical circuits, such as series and

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parallel circuits. In their course of Didactics of Science and Technology, they study the current distribution in series and parallel circuits during two periods each lasting 3 hours.

TABLE I
QUESTIONNAIRE AFTER FORMAL TEACHING: CURRENT SOURCE MODEL IN DC CIRCUIT

Question # 1

In Fig. 1, bulb A shines normally, bulb B shines moderately, and bulb C does not shine. The total current is 0.6 A and the electric power of the battery is 12 W. In your opinion, is the following statement true or false: If we open the switch and place an electrical wire across the bulb C as shown in Fig. 2 and we close the switch, the electrical power delivered by the battery would be:

❒ Less than 12 W ❒ Greater than 12 W ❒ Equal to 12 W

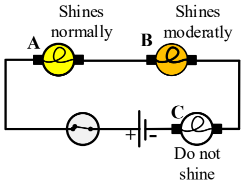


Fig. 1 Three bulbs are connected in series with a switch (close) and a battery

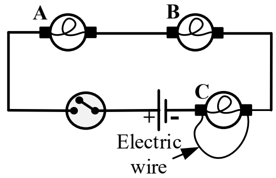


Fig. 2 Analysis of a short-circuited bulb in a series circuit

Question # 2

In Fig 3, the bulbs A and B have the same brightness. We connect an electrical resistance between these two bulbs as shown in Fig 4. If you turn off the switch, the lighting of bulb A will not be affected while that of B will decrease:

❒ True ❒ False

Explain your choice of answer:

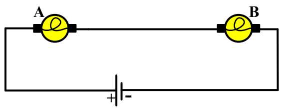


Fig. 3 Two bulbs are connected in series and a battery

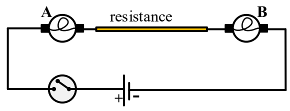


Fig. 4 Analysis of the current in a series circuit when a resistor is added

Question # 3

In the Fig. 5, the three bulbs A, B and C are identical, and they will light up if the switch is closed. The battery delivers a current of 0.9 A.

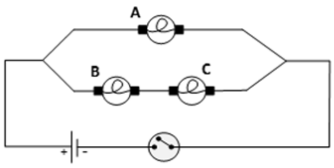
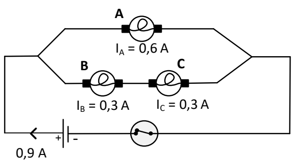


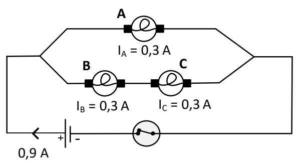
Fig. 5 Parallel Circuits

Indicate for each of the following diagrams (Fig. 6), if each bulb is passed by the indicated current:



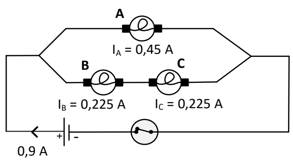
❒ Yes ❒ No

Explain your choice of answer:



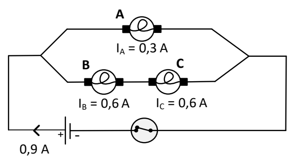
❒ Yes ❒ No

Explain your choice of answer:



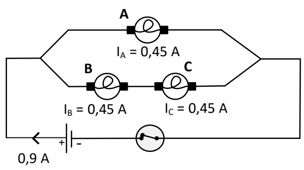
❒ Yes ❒ No

Explain your choice of answer:



❒ Yes ❒ No

Explain your choice of answer:



❒ Yes ❒ No

Explain your choice of answer:

Fig. 6 Analysis of current distribution in a parallel circuit

TABLE II
TWO-TIER DIAGNOSTIC TEST

Question # 1

In Fig. 1, bulb A shines normally, bulb B shines moderately, and bulb C does not shine. The total current is 0.6 A and the electric power of the battery is 12 W. If we open the switch and place an electrical wire across the bulb C as in Fig. 2 and we close the switch, the electrical power delivered by the battery would be:

❒ Less than 12 W ❒ Greater than 12 W ❒ Equal to 12 W

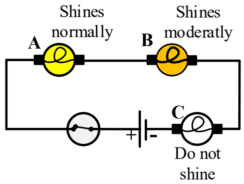


Fig. 1 Three bulbs are connected in series with a switch (close) and a battery

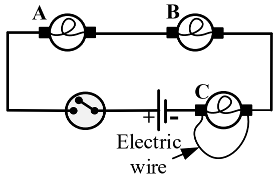


Fig. 2 Analysis of a short-circuited bulb in a series circuit

Which of the following explanations justifies your answer?

❒ [Equal to 12 W] Shorted bulb C by placing a wire at its terminals will not change the electrical power since it did not already resist the flow of the current, because it did not shine. While the intensity passes through a wire where the bulb is extinguished, there is no difference in resistance and no change in electrical power.

❒ [Greater than 12 W] Since there will be less resistance because of the short circuit (the wire placed at the terminals of C), the intensity of the current will increase in this circuit. Increasing the intensity of the current will increase the power, since the power depends on the voltage and current intensity (P = U.I).

❒ [Less than 12 W] By shorting the bulb C (electric wire placed at its terminals), we reduce the total resistance, so the battery does not need to provide as much electric power.

❒ [Equal to 12 W] The formula for the power is: $P = U.I = (U_A + U_B + U_C). I$.
If the bulb C is short-circuited (the wire placed at its terminals) then the voltage at its terminals is zero ($U_C = 0$ V) as when it does not shine. So, there is no change for the total power.

Question # 2

In the Fig. 3, the bulbs A and B have the same brightness. We connect an electrical resistance between these two bulbs (Fig. 4).

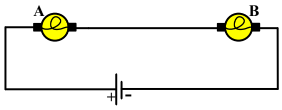


Fig. 3 Two bulbs are connected in series and a battery

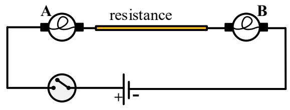


Fig. 4 Analysis of the current in a series circuit when a resistor is added

If you turn off the switch, the lighting of bulb A will not be affected while that of B will decrease:

❒ True ❒ False

Which of the following explanations justifies your answer?

❒ Bulb A will not be affected since the resistance is placed afterwards. Therefore, the electric current passing through bulb A will not be affected, but it will be affected for bulb B.

❒ The electric resistance does not influence the brightness of the bulbs.

❒ The lighting of both bulbs will be affected since the amount of the current passing through the battery will decrease because of the electrical resistance.

❒ The brightness of the bulb B will decrease since the current comes from the (+) and that the electric resistance hinders the current.

Question # 3

In Fig. 5, the three bulbs A, B and C are identical, and they will light up if the switch is closed. The battery delivers a current of 0.9 A.

Indicate for each of the following diagrams (Fig. 6), if it is true or false for each bulb is passed by the indicated current:

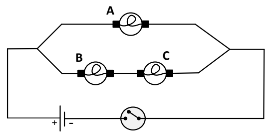
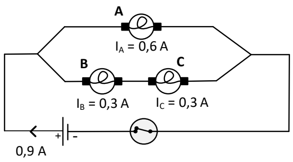
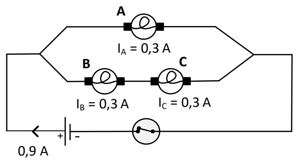


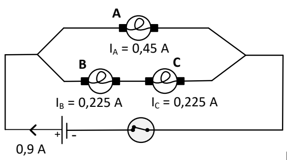
Fig. 5 Parallel Circuits



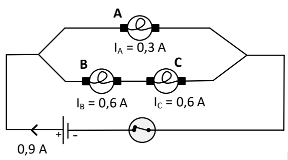
❒ True ❒ False



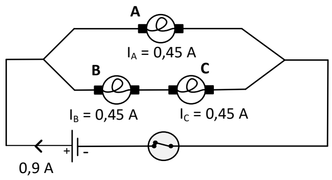
❒ True ❒ False



❒ True ❒ False



❒ True ❒ False



❒ True ❒ False

Fig. 6 Analysis of current distribution in a parallel circuit

Which of the following explanations justifies your choice of answer?

- ❒ In a parallel circuit, the current divides according to the needs of each branch. The branch composed of bulbs B and C will therefore receive more current. Since B and C are connected in series, they are crossed by the same current.
- ❒ The battery will divide its current equally by the number of bulbs, the latter being identical.
- ❒ The 0.9 A divides when it arrives at the node. It will divide in two, because the voltage of each branch is equal to the total. So, in A, there will be 0.45 A and in B and C, there will also be 0.45 A, because in series, the intensity remains the same.
- ❒ In this circuit in parallel, the current of 0.9 A divides. At the node, I will have 0.9 A to divide in two: A = 0.45 A; B and C = 0.22 A.
- ❒ In a parallel circuit, the total current is shared at the connections. In addition, the current will pass more easily to bulb A because there are fewer obstacles (compared to the bulbs B and C). The current will be able to circulate more freely and will be of higher intensity.

2. Methodology

We proceed to elicit their alternative conceptions with classical methods such as a paper-pencil questionnaire. We have retained three questions with two choices (True or false), and they had to justify their choice (see Table I). The stage of justifications is important since it allows to be sure that the choice of the student is not unpredictable and is founded on conceptual reasoning. For that, the questions selected cannot be solved by referring to formulas or techniques learned mechanically.

3. Analysis of the Data of the Paper-Pencil Questionnaire: Question 1

To analyze their answers, we grouped the responses into categories that ranged from four to six, depending on the question. The misconceptions identified are presented in the two-tier diagnostic test developed below.

B. Development of the Two-Tier Diagnostic Test

For each question (Table I), we retained only four categories, including the right answer category. Thus, we have eliminated those that are not representative of all students, such as the one grouping only 2 or 3 out of the 80 respondents and those grouping the answers indecipherable, off-topic or incomplete.

For each question, the student must assess the veracity of the statement (true/false) and then choose from four categories of answers which are confirmed with his initial choice of solutions. Of the four response categories, one is right, and the others are false (see Table II).

III. Conclusion

Aware of the limits inherent in a qualitative type of research, our work allowed us to conclude that the pre-service teachers construct erroneous conceptions of the current source despite teaching. How, under, such conditions, the teachers can help the students to make the changes to their conceptualization necessary for the correct understanding of the current from the power supply in DC circuits. For that, researchers claimed that teachers must diagnose their students' understanding before teaching to take this into account. The two-tier diagnostic test developed in the present research will help teachers to identify their alternative conceptions about the current source.

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