DEVELOPING LABORATORY EXPERIMENT FOR ELEMENTARY PRE-SERVICE TEACHERS: DIAGNOSTIC OF SIMPLE ELECTRIC CIRCUITS WITH ELECTRICAL INSTRUMENTS (AMMETER AND VOLTMETER)

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ABSTRACT

The present research has for object to bring 134 elementary pre-service teachers from Quebec in Canada to do activities of laboratories with respect to the analysis of electric circuits (series and parallel). During these sessions of six hours, they did several measures of the intensity of current (ammeter) and voltage (voltmeter) with a multimeter. We will see in this communication that, in spite of the difficulties met by the students to use this instrument, some succeeded in appropriating its mode of operation while familiarizing themselves with the notions of current and voltage as can be demonstrated by the results of a questionnaire paper-pencil of a length of sixty minutes we passed to them at the end of the experimentation.

Keywords: *Preservice teachers, elementary school, laboratory, electrical circuits, multimeter*

Introduction

Throughout the world, the majority of the curriculums propose to elementary school teachers to introduce their pupils to the basic notions of physics, chemistry and biology. Unfortunately, most teachers cannot dispense such teaching adequately because of serious gaps associated with their level of scientific formation (Mumba et al., 2015). In spite of this report, few researches develop strategies to help teachers acquiring a basic scientific formation (Webb, 1992; Criado-Carmona, 2010). For example, the researches achieved by Webb with teachers' demonstrate that they succeeded in using an ammeter to observe that the intensity of the current in different points of an electrical circuit is constant in given one time. The present research pursues the same objective and presents the results of a written questionnaire on the pre-service teachers' conceptions about the use of multimeter to measure electric quantities such as voltage and current.

Population and methodology

To identify the conceptions of 130 pre-service teachers, we have in a first time constructed a paper-pencil questionnaire of a length of sixty minutes which is composed of 4 questions (see appendix). This questionnaire aimed to verify if pre-service teachers understood that they must always place the ammeter in the branch of the circuit where they want to measure the current and that they must place it to the terminal of a component to measure the voltage at its boundary-marks. Then, we compiled the answers they gave, a question at a time, each taken separately. For each of them, we regroup the answers in distinct categories, the number being variable from one question to the other, according to the different answers given by pre-service teachers. Let's note that this categorization serves us to make the distinction between their correct, incorrect and partially correct answers. To qualify in such a way, we compared them to the answers of our questionnaire. Finally, we interpreted the set of the categories identified in order to put in evidence the constructed conceptions. The questionnaire was given to the pre-service teachers three weeks after having achieved experimentations which occurred during two periods, each of duration of 3 hours, in the context of a course on didactics of sciences and technologies.

Construction of the questionnaire and categorization of the answers

The student had to explain the experiment to achieve in situation of laboratory to measure the electric current crossing a bulb connected in series with two bulbs and a battery.

In this case, one must open the circuit and place the multimeter used in ammeter where according to the principle of the conservation of the total charge in given one time. The analysis of data brought us to identify two categories of answers. We presents below each of these two categories, followed by the justification advanced by a student as example:

Category 1 (N = 78; 60%) - the proposed branching is adequate - inserts the multimeter as ammeter in the circuit:

"It is necessary to disconnect the wire that joins the two bulbs to put the multimeter used like ammeter in the circuit. In series, the current is everywhere the same, then one can place the instrument after or behind the bulb 2 to measure the current that crosses it."

Category 2 (N = 52; 40%) - the proposed connecting is erroneous - places the ammeter at the two terminals of the bulb of which one wants to measure the current that crosses it:

"In a series circuit, the current could be measured at any place of the circuit since it is everywhere the same. One must put in contact the ammeter with the two boundary-marks of the bulb. One places a first wire of connecting to a boundary-mark of the bulb, one plugs the two wires to the ammeter and one makes his reading.

Question #2

The student had to measure the intensity of current produced by a battery connected to a set of three parallel bulbs. In this case, one must disconnect the connecting are either at the entry of the battery, either at the exit of the battery, and to plug the instrument in series with the battery. Four categories of answers have been identified following the analysis of the justifications given:

Category 1 (N = 77; 59%) - the proposed branching is adequate - places the multimeter used like ammeter at the exit of the battery:

"In this way, the ammeter measures the current provided by the battery because it is in series with this one. After having crossed the ammeter, the electric charges divide in the three branches that are in parallels. Thus, it is necessary to plug the ammeter before the charges divide in the three branches. One could also plug at to the return of the charges."

Category 2 (N = 23; 18%) - the proposed solution is correct but doesn't respect the data provided in the question, to know how to do only one measure - measures the current in each of the three branches of the circuit :

"To know the current produced by the battery, it is necessary to calculate the current of every exit of the circuit because it is parallel circuit: $I_{battery} = I_1 + I_2 + I_3$."

Category 3 (N = 22; 17%) - the proposed connection is false - places the multimeter used like ammeter at the boundary-marks of the battery:

"$I_{totale} = I_1 + I_2 + I_3$ in parallel. One must connect it to the boundary-marks of the battery in order to measure the current (to measure the total number of electrons that moves in the circuit)."

Category 4 (N = 8; 6%) - the proposed connection is false - places the multimeter in series with the bulb 1:

"I plugged the ammeter in series in the circuit because I know that the principle of conservation of the charges applies in series circuit, and not in parallel. Therefore, that the current is always the same in series in a circuit: $I_{battery} = I_1$."

Question #3

The student had to know if the set-up achieved by the pupil is adequate and that he can close the switch to measure the current crossing the bulb. In this situation, we wanted to verify if the

students understood well that the instrument must always be inserted in the circuit and not to the boundary-marks of the component to measure the current. Thus, in the last case, the achieved set-up is erroneous. Two categories of answers have been identified:

Category 1 (N = 76; 58%) - the achieved set-up is erroneous since the probes of the multimeter are put at the boundary-marks of the bulb and therefore, the instrument will display no value; it would be necessary that the multimeter is connected in the circuit:

"The two wires of the multimeter (here used as ammeter) should not be connected to the boundary-marks of the bulb, but connected with wires in the very circuit; one measures the current and no the voltage at the bulb boundary-marks."

"The mistake occurs at the level of the ammeter. An ammeter must be plugged in series in the circuit and not at the boundary-marks of the resistance. It will be therefore impossible for the ammeter to read and provide a measure."

«[..] Il devrait plutôt être placé en série avec l'ampoule pour avoir la bonne intensité de courant du circuit électrique.»

" [..] It should rather be placed in series with the bulb to have the correct intensity of the current in the electric circuit."

Category 2 (N = 54; 42%): The achieved set-up is correct because the bulb, the battery and the switch are in series and the instrument is placed at the terminals of the bulb.

"The wire of the multimeter is correctly connected to the COM and in the A for the ammeter (current). My arrow is positioned well in the dial of the ammeter and at the scale of 10A since my measure of the intensity of the current doesn't possibly require more than 10A. The connections in his circuit are well done (battery, switch, and bulb)."

Question #4

For this question, we placed the student in a teaching situation where he would be brought to verify if the connection achieved by some pupils to measure the current with the use of a multimeter is appropriated. The problem aimed to verify if, for the students, it is about an open circuit and if, for them, one had to close the switch to measure the current. Let's note that the set-up achieved by the pupil is correct and that the switch plays the role of a simple conductor. On the other hand, if one closes the switch, the multimeter will be placed to its terminals and one cannot measure the current, because it is necessary that it is placed in the circuit. Four categories of answers have been identified:

Category 1 (N = 42; 32%) - the achieved connection is correct:

"The set-up is correct since to find the intensity of the current, it is necessary to introduce the device (ammeter in the closed circuit). He used a switch for that to make. He plugged one of these wire in the COM and the other in the 10A, he adjusted the multimeter to 10A to find the intensity. In series, in a closed circuit the intensity is everywhere equal, therefore $I = I_{battery} = I_{bulb}$. No matter where he will place his ammeter in the circuit, he will get the intensity of the electric current crossing his bulb."

Category 2 (N = 42; 32%) - one must not place the multimeter to the terminals of the switch, but rather in the circuit. The students of this category advanced an incomplete answer, because it is true that one must not only place the instrument to the terminals of the switch if this last is closed, what is not the case of the connections achieved by the pupil.

"The multimeter should not be at the boundary-marks of the switch. It should be connected in series with the help of two connecting wires."

Category 3 (N = 14; 11%) - the achieved circuit is not open and no current circulates, because the switch is open. For these students, a switch in a circuit permits either to open it either to close it,

what is quite just. However, in the present situation, the switch placed as it is acts like conductor and close the circuit:

"In the first place, it constitutes an open circuit because the switch is not closed. As a consequence, the charges cannot circulate freely. The rest of the circuit in series is well done. If the switch is closed, the bulb should be luminous."

Analysis of the results

The categorization of the answers advanced in the case of the question 1 show that several students (60%) understood well how one must connect a multimeter as ammeter to measure the intensity of the electric current crossing a bulb in a circuit in series. In spite of this encouraging result, 40% among them have the difficulty to use correctly the multimeter as ammeter while connecting it to the boundary-marks of the bulb. According to us, this difficulty probably results from confusion between the voltage (to the boundary-marks of a component) and the current (in a branch). The situation is similar in the second problem, because a majority of pre-service teachers (59%) connected the multimeter correctly to measure the current produced by the battery. Let's note that in the case of this problem, 18% of them were not able to make the connecting that permits to measure the current directly, as asked. However, they proposed a correct solution that consists in measuring the current crossing every bulb and then to add them. In this case, we have been surprised to note that the percentage of students (17%), having proposed to place the multimeter in series with the battery to measure the current, decreased distinctly, compared to question 1. In the case of the third question, 58% advanced a correct answer while affirming that one must not place the multimeter at o the terminals of the bulb. On the other hand, the number of students having advanced an erroneous answer is important (42%). These students ignore that such connection will damage the instrument and therefore that one won't be able to do any measure. In question #4, the number of students having proposed a correct answer (32%) decreased distinctly compared to the other questions. The reasons that explain this weak percentage result among others from the role usually assigned to a switch, namely the opening or closing of a circuit. The answers for this question reveal implicitly that the law of the conservation of total charge is not assimilated. Indeed, for several pre-service teachers, one must place the ammeter measuring the current crossing a component solely before or after this component. According to us, it implies that the current is not everywhere the same in given one time. This false conception persists in spite of the multiple measures achieved in the laboratory sessions.

Conclusion

In spite of the difficulties met to use the multimeter as ammeter or as voltmeter, an average of 50% of the pre-service teachers succeeded in appropriating the mode of working of the multimeter, while familiarizing themselves with the notions of current and voltage. The results of our research show that it would be necessary to develop a lot more strategies for the acquisition of the concepts of current and voltage by experimentation. When the use of the multimeter is acquired, one can analyze the working of electric circuits with the notion of electric power, and this continuation to the measures of current and voltage.

Reference

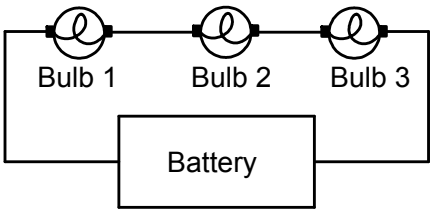
1. Criado, A-M and Garcia-Carmona, A. (2010). Prospective Teachers' Difficulties in Interpreting Elementary Phenomena of Electrostatic Interaction: Indicators of the status of their intuitive ideas. International Journal of science education, 32(6), 769-805.

2. Mumba, F., Mbewe, S. and Chabalengula, V-M. (2015). Elementary School Teachers' Familiarity, Conceptual Knowledge, and Interest in Light. International Journal of Science Education, 37(2), 185-209.

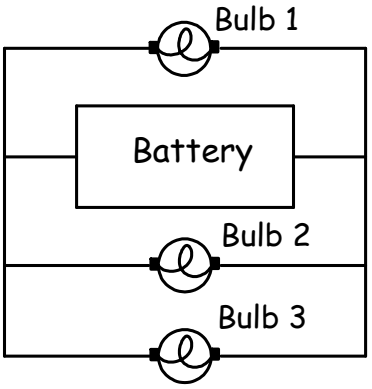
3. Webb, P. (1992). Primary science teacher's understanding of electric current, International Journal of Science Education, 14(4), p. 423-429.

Appendix
Paper-pencil questionnaire

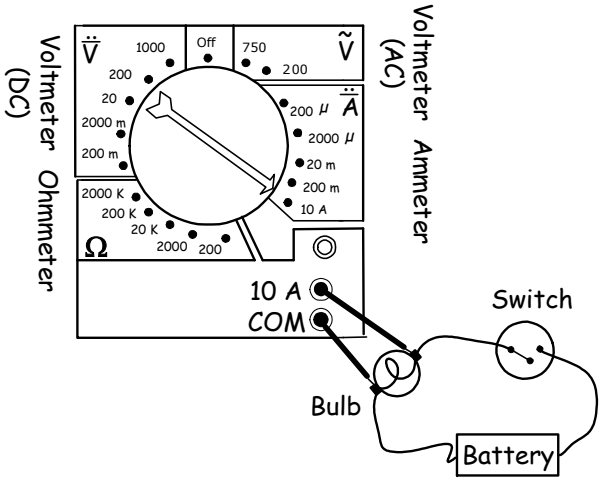
Question #1
How to connect a multimeter in the circuit shown to measure the intensity of the current that crosses the bulb #2? Describe all necessary manipulations to connect your multimeter.



Question #2
How to connect a multimeter in the circuit shown to measure the intensity of the current provided by the battery? Describe all necessary manipulations to connect your multimeter.



Question #3
At the time of a laboratory session on the use of multimeter to measure the intensity of the electric current crossing a bulb in a circuit constituted by a battery, a switch and connecting wires, you instructed your pupils not to close the switch as long as you had not checked their set-up. One of the pupils asks you to verify if his set-up is correct. Identify the elements of connection that are correct or erroneous. In the case of erroneous connections, what can be the consequences? Justify your answer.



Question #4
At a laboratory session on the use of a multimeter to measure the intensity of the electric current crossing a bulb in a circuit constituted by a battery, a switch and of the connecting wires. One pupil asks you to verify if his set-up is correct. Justify your answer.