PROCEEDINGS OF SCIENCE

Achievements of Gymnasium Students in Montenegro on Electric Circuit Test

Mira Vučeljić[a],* M.Šćepanović[a], N.Šarović[b]

a *University of Montenegro, Faculty of Natural Science, Podgorica, Montenegro*

b *O.Š. 'Luka Simonović', Nikšić , Montenegro*

E-mail: vmira@ucg.ac.me, mara.scepanovic@gmail.com, natasasarovic993@gmail.com

Electric circuits are an important element of physics class. However, many students leave secondary school without having an adequate conceptual understanding of simple circuits. Voltage in particular is a difficult concept since students understand voltage as a property of the electric current. Gymnasium students in Montenegro did test which contained problems of understanding concepts of electrical circuits. Percentage of students who understand a concept of current is relatively high, but percentage of students who succeed to deal with voltage concept is decreasing rapidly. This investigation reveals the problems that students have on microscopic level about the charges in battery. Since great fraction of students assume that only battery determines the value of current same as the charges from battery flow to wire, it implies that more time, more lessons, should be devoted to this area. Those findings should be useful for teaching community in creating pathways that will replace those wrong mental models or ideas with scientific ones.

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*Speaker

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1. Introduction

During the eighties and nineties, physics education research has established the great deal of instruments to assess the basic knowledge state of students. Every student begins physics with a well-established system of commonsense beliefs about how the physical world works derived from years of personal experience. Physics education research has established that these beliefs play a dominant role in introductory physics [1]. Although teacher provides students correct information about physics phenomena or physics law, students construct their own ideas or models which differ significantly from scientific and we called them a misconception. Those misconceptions are incompatible with scientific concepts in most respects and conventional physics instruction produces little change in these beliefs. The implications could not be more serious. Since the students have evidently not learned, for example the most basic Newtonian concepts, they must have failed to comprehend most of the material in the course. They have been forced to cope with the subject by rote memorization of isolated fragments. Instruction that does not take misconception into account is almost totally ineffective, at least for the majority of students. The Force Concept Inventory (FCI), very popular instrument to assess the basic knowledge state of student in Newton mechanic [1], was given to high-school (Gymnasium) students in Montenegro. Result of this investigation presented in [2] has shown that kinematics problems are the most difficult among the Montenegro sample. Since a physics education research emphasizes that graphical and diagram representation are very useful to describe the demonstrated motion and is powerful mechanism for development of students understanding of kinematics, an investigation on student's ability to interpret kinematics graphs was done among Montenegro high-school (Gymnasium) students. Results obtained in Test of Understanding Graphs-Kinematics (TUGS-K), author R. Beichner [3] were compared with the results obtained in USA and presented in [4]. Problems of understanding a key concept in electromagnetism among gymnasium students in Montenegro were investigated too and presented in [5].Since the common sense beliefs influence understanding of Newton concept, someone should expect that it is not the case in lessons on electric circuits since they are intrinsically based on microscopic effects. Unfortunately, in attempting to understand the behavior of electric circuit, students appear to construct a mental model of electric current, potential difference etc. The difficulties students encounter with the understanding of key concepts can lead to the wrong understanding of the electric circuit based on different components working separately. Students do not manage to deal with changes made to a circuit in holistic manner. Investigation focused on problem of key understanding of electrical circuits revealed that students construct a mental model- misconception, of electric current, potential difference, function of the battery etc. According to Shipstone [6], there are five dominant mental models for current in simply circuits. Unipolar model-current flow from battery to bulb (no current from bulb to battery), clashing currents model (current flow from both terminals to bulb), attenuation model (first bulb provide more brightness that second one because the first one gets more current), sharing (equal brightness but not equal current). A number of authors have reported that many students seem to believe that the amount of current supplied by a battery is always the same regardless of the number of components in the circle ("battery autonomy"). In case of voltage and potential, some investigations indicate that some students relate a voltage/potential difference as "strength of the battery" or they believe that pd (potential difference) has a same concept as electric current. Those mental models exist separately among students; even those models are sometimes contradictory. Intention is that teaching instruction help students alternative ideas replace with scientific. Diagnostic test about conceptual understanding of electric circuits, in following text we will use abbreviation Electric Circuits Test (ECT), which was developed at University of York, see [7], was offered to Gymnasium students in Montenegro. We tried to find out what mental models about electric circuit are dominant among the gymnasium students in Montenegro. Those findings should be useful for teaching community in creating learning pathways that can replace wrong model with scientific one.

2. ECT

ECT was done by 107 high-school (Gymnasium) students in Montenegro. Students were at third year. Maximum number of points that can be obtained in ECT is 25; maximum number of points in Montenegro sample was 19.5. Average number of points obtained in Montenegro sample was 9.4. Test consists of 17 questions and item difficulty index-ID (which is the number of correct answers divided by the total number of students that did ECT is presented on Fig.1. Items on this test were dominantly two tier questions, designed to reveal some prevailing mental model about simple electric circuits. Two –tire questions consist of two sub question. In first tire, students are asked about some parameter of electric circuits and second tier ask student to explain their reasoning. Students were scored if they answered correctly on both part of item.

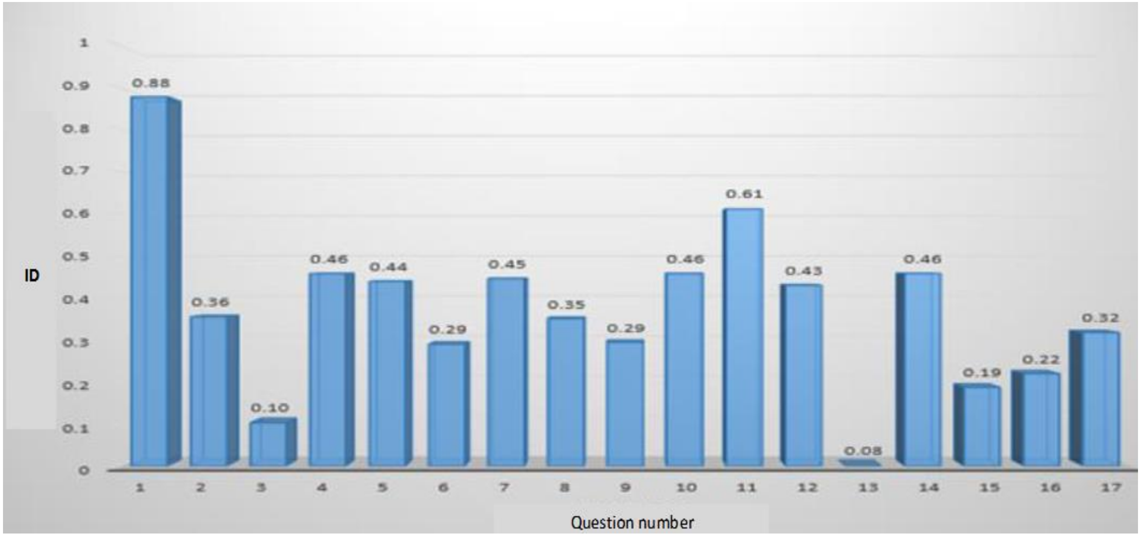

FIG. 1. *Item difficulty index-ID on ECT questions.*

ECT which was given to gymnasium students in Montenegro was probing ideas of mental models of current, electron flow in circuit, influence of the resistance on current and concept of potential difference.

What mental models about electric current, are dominant among our student was testing by item 1. It is the easiest item in the test. Students have to compare electric current at points A and B, before and after the resistor. ID is 0.88. High result on item 1 was confirmed by the first tier of item 7 which is about electric current at point's B and C (see Fig.2). 83% answered that electric current in B and C is equal and confirmed that scientific model is dominant among our sample. Anyway, the total ID of item 7 is 0.45 because second part of the question, about electric currents at B and D appears to be more difficult for them. There were no students with unipolar or clashing electric current model in our sample.

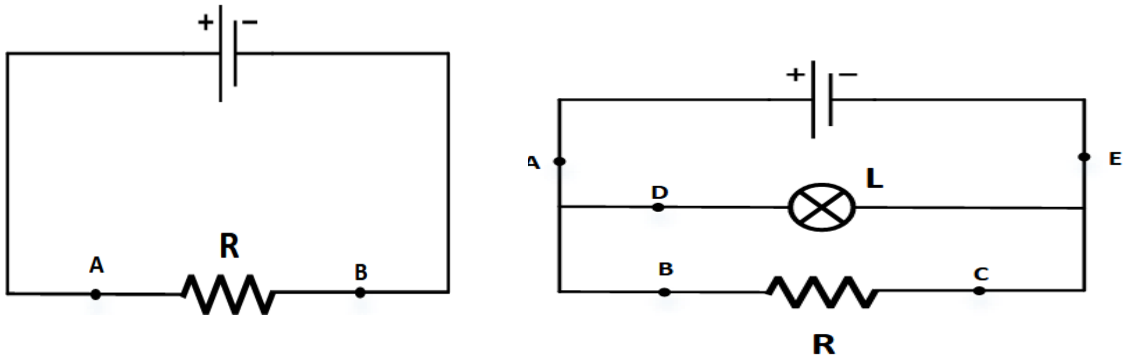

FIG. 2. *Electric circuits for questions 1 and 7 respectively. Student should compare current at point A and B, same as in B and C. [7]*

Electron flow and moving of charges in battery was tested by item 2. For a simple circuit consist of battery and the bulb there are six statements, see Fig.3, about a flowing the electrons through a wire and process occurring in battery. Students should choose are the statements true or false. About 50 % of students answered correctly on statement *c* but only 20% answered correctly on statement *a*. Students dominantly assume that charges are suited in battery and flow out of battery into the wire.

Low performance on statement *a* in item 2 was quite surprising and we have examined a textbook in order to find out is there some mistake. In order to explain that electron current will flow only when there is a potential difference authors used an analog example of water flow in circle pipe connected to a two vertical pipe. Water will flow only when there is a height difference in two vertical pipes same as electron flow when there is potential difference in electric circuit. This analogy of water flowing with electrons current is useful for explaining that potential difference is necessary for electron flow. Could this analogy with water flowing create a wrong perception among the students that battery is a kind of reservoir of electric charges where all the charges are situated and they flow out when buttery is connected same as water flow from water reservoir when pipe is open, should be analyzed in some further investigation.

	Statement
a)	Before the battery is connected, there are no electric charges in the wire. When the battery is connected, electric charges flow out of it into the wire
b)	When the circuit is connected, the free electrons gain kinetic energy. As they move round, the free electrons give this energy to the components they pass through.
c)	The battery, the wire and the bulb filament are full of charges, all the time. When there is closed circuit, the battery makes all these charges move round together.
d)	Before the circuit is connected up, there are free charges in the battery only. There are no free charges in the wires or the bulb filament
e)	When the circuit is connected, the free electrons which moving are absorbed by the bulb to produce light.
f)	Before the circuit is connected up, there are free charges in the battery, the wires and the bulb filament.

FIG.3 . *Item number 2. Author: Borg Marks, J [7]*

Comparing a results on *a* and *c* we can conclude that students are confused about electron flow in wire (are electrons situated in wire or they flow out of battery) same as a process occurring in battery. This situation implies that teacher should spend more time in explaining a roll of the battery in electric circuits.

Third domain of ECT was analyzing influence of the resistance on electric current in electric circuits. Among the most difficult items was number 3, (ID-0.1), about electric current, when resistors are connected serial. Students saw a scheme of the simple electric circuit with one resistor. Question is what happened to the electric current when we added a same resistor connected serial. About 40% of students answered that electric current will be smaller but not zero, but 50% give a wrong explanation that two resistors need more electric current than one of its own. Same situation is tested with item 6 (ID-0.3), circuit consist of battery and variable resistor. Question is what happened to the electric current when resistance is increasing. Percentage of correct explanation, the battery cannot push as a big a current through larger resistor, is increased compared with item 3.

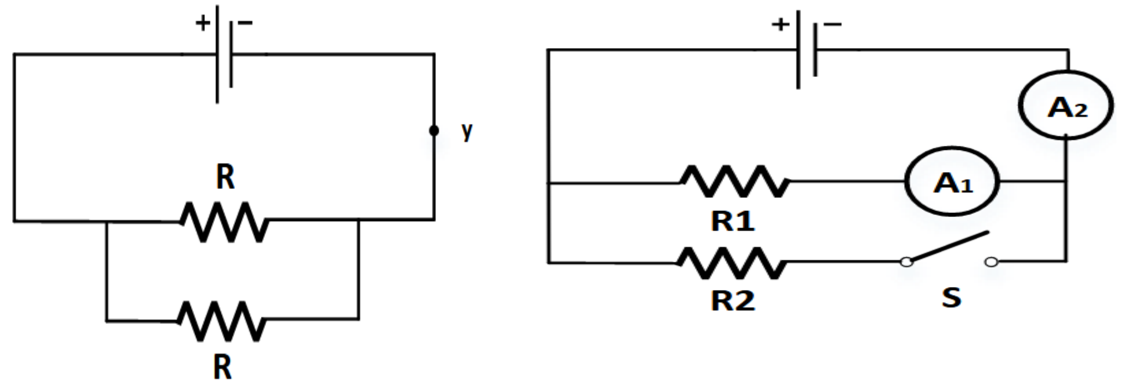

FIG.4 *Circuits for item 4 and 16 respectively. Students are asked about current at point Y and reading of A2 when switch is closed. [7]*

ID index is better for questions treated circuits with resistor connected parallel. Situation that students have better results in circuits connected parallel is confirmed in [8] too. In item 4(ID-0.46), students saw a scheme of the simple electric circuit with one resistor. Question is what happened to the electric current at point Y when we added a same resistor connected parallel, Fig.4. About 55% of students said that electric current will get bigger and 67% of student chose a correct explanation that the second resistor provides an extra part for electric current to flow. Since we scored only answer with both correct question and sub-question (explanation) that makes that ID for item 4 is 46%.
Same situation was tested in question 16 (ID-022). A circuit for item 16 is presented on Fig4. Question is about reading of ammeter 2 when switch is closed. Student did not recognize that situation is same as in item 4 and percentage of correct answer was halved. These results indicated that students' knowledge is quite fragile when they are confronted with same problem in new situation or problem in different context that they learned during the class.
Concept of potential difference is the most difficult for students so the most difficult item in the test, item 13, belongs to this domain. Students have to predict a potential difference at points A and B, see Fig. 5, in situations when switch is closed or open. Only 8.4% answered correctly about pd on open switch (right side circuit). Other students answered that when there is no current (open switch), pd is zero. This situation is dominant in majority of research about this problem. Secondary school students do not develop an independent voltage concept but interrelate it to the concept of electric current. That means that voltage is seen as a property of the electric current. Wrong conclusion that in case of open switch,

potential difference is zero students base on wrong interpretation of Ohm-s law, which is in textbook presented with formula ΔV=RI, so students assumed, since there is no current there is no voltage too.

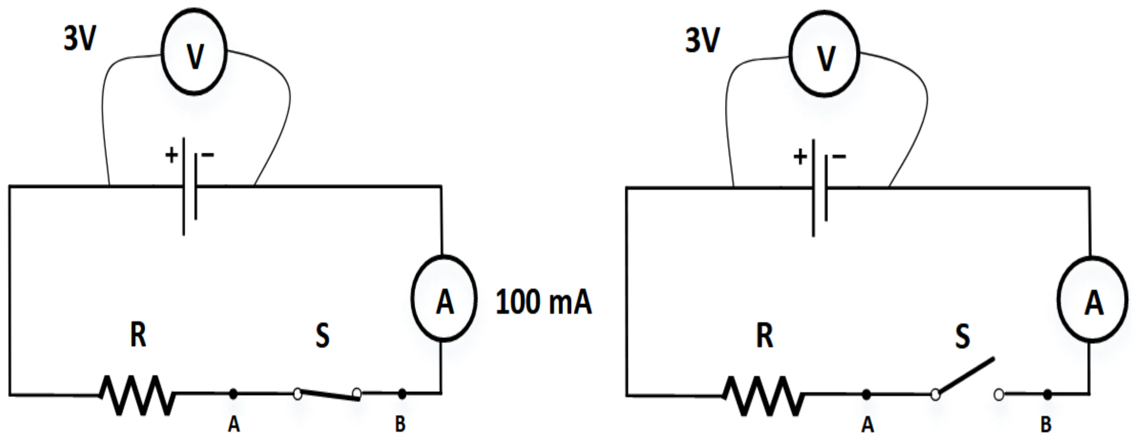

FIG.5 *Electric circuits in item 13. [7]*

3. Discussion and instruction for teachers

Main purpose of this investigation was to get an insight what is a most dominant mental model or misconception among students in Montenegro. Percentage of students that has accepted a scientific model of electric current in our sample is relatively high. There were no students with a unipolar or clashing model. Result obtained in Montenegro sample has confirmed previous investigation that simple parallel circuit is easier for understanding than simple series circuits although series circuits student learn first. It is confirmed too that students have problem on microscopic level about the charges in battery. Since great fraction of students assume that only battery determines the value of current same as the charges are situated in battery and flow to wire, it implies that more time, more lessons, should be devoted to this area. Education community assumes that problems in electric potential arise from the fact that electrostatic and electric circuits are not integrate in coherent framework in traditional lessons. While the concepts of electric charge, electric field and electric potential play an important role in chapters of electrostatics, these concepts are rarely even mentioned in chapters of simple circuits. As these chapters focus on directly observable or measurable quantities such as current or resistance, the danger is that students think of circuits and electrostatics as two completely unrelated topics. That can be a reason why students do not realize important role of the electric potential play in circuits. Since the electric field present a underlying concept mediating between the voltage and electric current, teacher should spent more time to develop a microscopic view about moving the electrons , their scattering by surrounding atoms and connection between the electric field and electron drift velocity which determine a electric current .

While performance on standard questions on some very fundamental ideas was satisfactory, it dropped significantly for less familiar situations when application of ideas were required. Analyses of answers to two or more related questions suggested that most students' understanding is fragmentary and is not integrated into a coherent framework. Some pairs of questions in the test probed the same idea in different contexts. We might expect student's answers to these to be consistent. But they are not; this suggests that the student does not see the two situations as similar and is focusing on contextual details, or that they are simply confused and guessing answers. Thus suggesting that teacher should spend more time in qualitative analyses of the electric circuits. Quantitate problems should not be involved until students teach a good conceptual knowledge.

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