DIREÇÃO DA CORRENTE ELÉTRICA - UM TÓPICO PARA DISCUSSÃO EM ESTÁGIOS INICIAIS DO ENSINO DE FÍSICA

ELECTRIC CURRENT DIRECTION – A TOPIC FOR DISCUSSION IN EARLY STAGES OF PHYSICS TEACHING

Priscilla Paci Araujo[1], Paulo Simeão Carvalho[2], Manuel B. Marques[3]

[1] Departamento de Física, Fundação Universidade Federal de Rondônia, Campus José Ribeiro Filho BR 364 km 9,5, 76801-059 Porto Velho, Rondônia, Brasil, priscillapaci@unir.br
[2] Departamento de Física e Astronomia, UEC, Faculdade de Ciências da Universidade do Porto, IFIMUP-IN, Rua do Campo Alegre, s/n, 4169-007 Porto. psimeao@fc.up.pt
[3] Departamento de Física e Astronomia, Faculdade de Ciências da Universidade do Porto, INESC-TEC, Rua do Campo Alegre, s/n, 4169-007 Porto. mbmarque@fc.up.pt

Grupo Temático 2 – Conteúdos educacionais – da produção à exibição
Subgrupo 2.1 – Produção de materiais didáticos: diferentes mídias, diferentes olhares

Resumo:
São conhecidas as dificuldades que muitos alunos apresentam na compreensão dos fenômenos físicos, que em alguns casos provêm das abordagens de ensino incompatíveis com as mais recentes teorias da aprendizagem e / ou da falta de ferramentas pedagógicas estimulantes e efetivas na aprendizagem. Um dos assuntos que causa dúvidas aos alunos no domínio da eletricidade é o tópico da corrente elétrica. Um teste de múltipla escolha sobre a direção da corrente elétrica em um circuito contendo um diodo, realizado por 83 alunos do curso de física da Universidade do Porto, confirmou que estes alunos se mostram confusos sobre a direção da corrente "real" e da corrente "convencional" e, assim, não identificam corretamente a direção da corrente elétrica em um circuito CC, porque eles não percebem que essa direção não é arbitrária. Isso justifica uma maior atenção ao assunto pelos professores e o desenvolvimento de uma abordagem pedagógica experimental para o ensino desse tópico nas fases iniciais do ensino escolar. Neste artigo, propomos uma atividade experimental para alunos do ensino fundamental e médio, abordando a direção da corrente elétrica em um circuito DC, onde usaremos lâmpadas e LEDs em uma abordagem P (prever) - O (observar) - E (explicar) baseada em ensino por inquérito. Usando um circuito elétrico simples com bateria de 3 V, lâmpada, fios e LEDs, os alunos terão a oportunidade de prever, observar e explicar os resultados experimentais de maneira crítica, concluindo que os LEDs podem fornecer informações precisas sobre a direção do corrente elétrica em um circuito.
***Palavras-chave**: sentido da corrente elétrica; POE; ensino experimental; aprendizagem significativa.*

Abstract:
The difficulties that many students present in understanding of physical phenomena, which in some cases come from the teaching approaches mismatched from the most recent theories of learning, and/or the lack of stimulanting and effective pedagogical tools, are well known. One of the subjects that cause doubts to the students in the domain of Electricity is the topic of electric current. A multiple choice test on the direction of electric current in a circuit containing a diode, done by 83 students of the physics course at the University of Porto, confirmed that these students are confused about the direction of the "Real" and the "conventional" current, and they do not identify correctly the direction of

the electric current in a DC circuit because they do not realize this direction is not arbitrary. This justifies a greater attention to the subject by the teachers, and the development of an experimental pedagogical approach for teaching this topic at early stages of school instruction. In this paper we propose an experimental activity for K-9 grade students addressing the direction of the electric current in a DC circuit, where we will use light bulbs and LEDs in a P (predict)-O (observe)-E (explain) inquiry-based learning approach. Using a simple electric circuit with a 3 V battery, lamp, wires and LEDs, the students will have the opportunity to predict, observe and explain the experimental results in a critical way, concluding that the LEDs can provide accurate information on the direction of the electric current in a circuit.
***Keywords**: electric current direction; POE; experimental education; meaningful learning.*

1. Introduction

One of the most intriguing procedures for young physics students is the identification of the direction of electric current in an electric circuit. Historically, the electric current *I* is defined as the average electric charge that flows a crossed section of an electric circuit, and by convention, its direction corresponds to the flow of positive charges [1,2]. This direction is not necessarily the same as that of charge carriers that are actually moving along the circuit (e.g. the electrons in a metallic conductor), although, in general, the sign of charge carriers is not important for the numerical electric circuit analysis.

In a school environment, it is usual to talk about this issue in terms of "conventional" and "real" direction of electric current, but without a careful and critical reasoning concerning these terms and the implication on students understanding.

In the Portuguese curriculum of 9th grade about the Electricity domain, in the subdomain Electric Current and Electric Circuits, we can find explicitly [3]:

- Descriptor 1.2: Associate the electric current with an oriented movement of electrically charged particles (electrons or ions) through a conducting medium.

- Descriptor 1.5: Indicate the conventional direction of the current and the movement of electrons in a circuit.

Descriptor 1.2 is somehow vague in the definition of the electric current direction, but descriptor 1.5 seems to clarify explicitly the difference between conventional direction of electric current and that of electric charges. However, as the examples used in the classroom are scarce and usually only involve the motion of electrons, students get the wrong idea that "real" (electric charge) current is always opposite to "conventional" current. Moreover, very often they do not realize adequately that the electric current direction is the conventional one and that in a DC circuit, that direction is not arbitrary.

We have confirmed our fears in a multiple-choice question involving a DC electric circuit with a non-linear element (a diode), with 83 students from Physics and Physics Engineering courses. The question is in Appendix A. The students had to indicate which diagram represented correctly the direction of electric current in the circuit. The results are presented in figure 1.

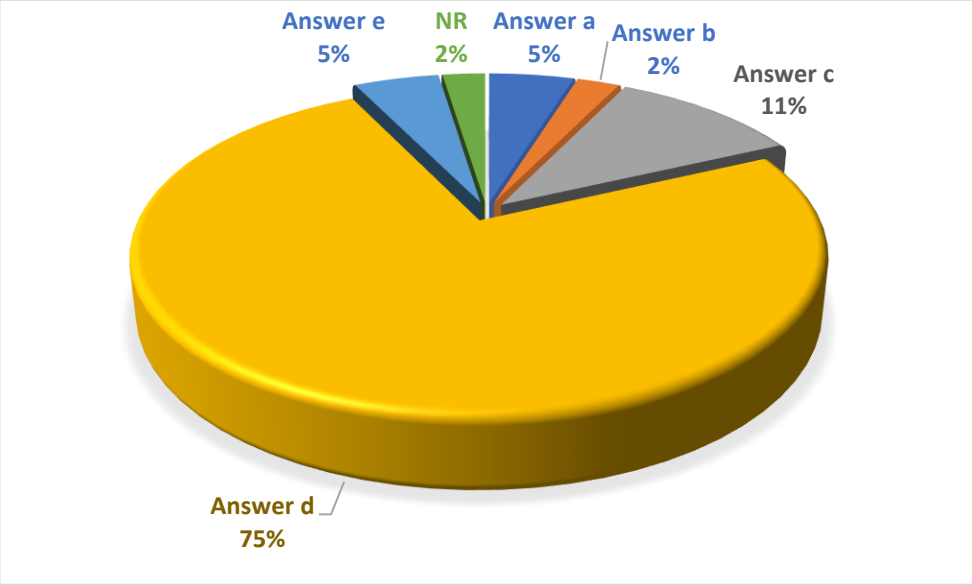


Figure 1: results from 83 students concerning the direction of electric current in a DC electric circuit.

Source: own authorship.

In our study, six students (7%) revealed problems on how a diode works and/or interpreting the symbol representing the diode concerning to the current flow (answers a and b); nine students (11%) mixed up electric current direction with charge carriers direction (answer c); and more worrying, four students (5%) believed that the current departs from both terminals of the battery (answer e). Two students did not answer the question (NR). For one reason or another, the truth is that 25 % of students from our sample could not identify correctly the electric current direction.

This result at university level is quite relevant about students' difficulties on this topic and justifies our attention for developing a pedagogical approach for teaching the direction of electric current in an early stage of curriculum.

2. The pedagogical approach

In order to reflect and generate a solution to the problem, we propose a pedagogical approach with an active learning methodology, where the students predict, execute the experiment, observe and draw their conclusions about the subject in a critical and reflexive way [4].

The proposal of an experimental activity about electric current for students of the fundamental (low secondary) level of education comes in accordance to the view of several authors: Bruner - that defends the spiral learning model, whereby students have the opportunity to view and review certain subjects at different levels of depth at different periods

of school life [5,6]; Vygotsky which is applied in our activity through group interaction for experimental activities and by contextualizing the content, and Ausubel - that deals with the importance of prior knowledge of the student, or rather the subsumers for meaningful learning [8]. In this perspective we propose an experimental activity to be implemented in an inquiry-based approach with K-9 grade students about electric circuits, a topic that will be reviewed by the students in secondary education (high school).

The experimental activity concerns electric current direction in a single DC circuit. We begin by introducing a challenging question to the students:

> "Peter read in a Physics book, that DC electric current has a well-defined direction in an electric circuit. This made him wonder whether DC electrical apparatus can operate with any sense of current or stop working if the direction of the current switches. What will be the answer?".

This is to focus the attention of students throughout the activity, which will allow them to discuss and answer the challenging question at the end of the work. In the following, we describe the steps to implement an interactive teaching methodology with a P(predict)-O(observe)-E(explain) approach [4].

We start the activity by presenting to students simple electric circuits, with a 3 V DC power supply (battery), a bulb lamp, a protective resistor, a LED and lead wires. The LED has a well-defined polarity as shown in figure 2. As students find out during the activity, this component enables the electric charge to flow only from the positive to the negative pole.

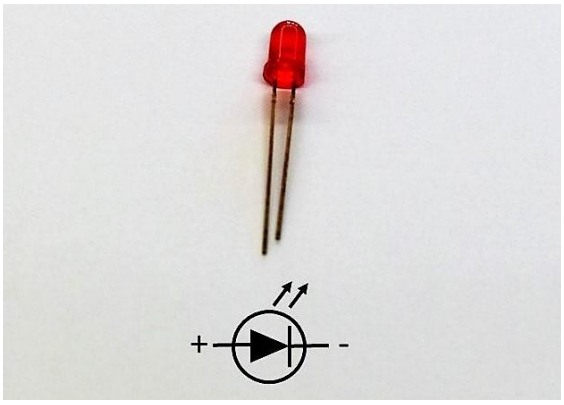


Figure 2: Photograph and schematic representation of a LED. The long leg corresponds to the positive pole. Source: own authorship.

The first circuit to present to students consists of a 3 V DC power supply (battery), a bulb lamp and lead wires (figure 3). In a DC electric circuit, does the direction of the electric current has a well-defined direction, or does it change with time?

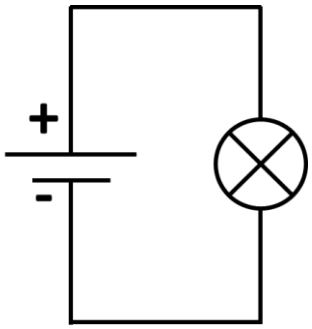


Figure 3: Circuit with a bulb lamp, lead wire and a 3 V battery. Source: own authorship.

Reversing the polarity of the battery, students observe that the lamp always emits light, which is not very conclusive about the direction of the electric current. What about when replacing the bulb in figure 3 by a LED in series with a protective resistance of 220 Ω? Now the results are quite different, as they draw the first conclusions: the LED lights only with one particular polarity of the battery!

To test further the results, we suggest students to build the circuit shown schematically in figure 4, in which a LED (with the protective resistance) is put in parallel with the bulb lamp (note that the resistance of 220 Ω only prevents the LED from burning).

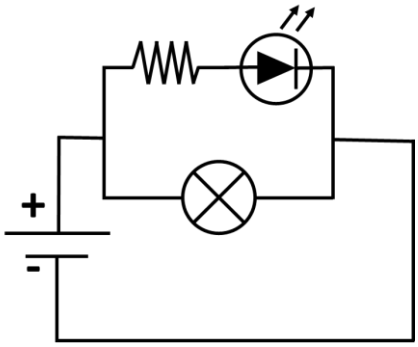
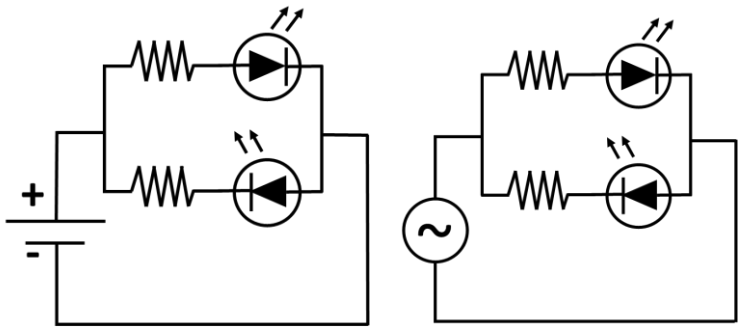


Figure 4: Electric circuit with a 3 V battery and lead wires. A protective resistance of 220 Ω is series with the LED is mounted in parallel with a lamp. Source: own authorship.

Based on the previous results and respective conclusions, students are at this point asked to predict what will happen to the LED and bulb in the circuit, with the indicated and reversed polarity of the battery. Then they turn on the circuit, make their observations and discuss the results. They will see that there is only one especific polarity of the battery for which both LED and bulb emit light, showing that the DC electric current has a well-defined direction and does not change in time. They will also see that the lamp always lights independently of the battery polarity. Therefore, the LED identifies the direction of the charge flow.

For the last part of this activity, students use two LED mounted in parallel, one LED with the polarity inverted in relation to the other. Two circuits are proposed: one with a 3 V

battery (DC circuit) and another with an adjustable frequency AC power supply (1 Hz or lower) (figure 5).



(a) (b)

Figure 5: Electric circuit with lead wires, where two LEDs are mounted in parallel with (a) a 3 V battery, and (b) an AC 3 V generator. Each LED has in series a protective resistance of 220 Ω. Source: own authorship.

By this time it is expected that students can predict that in circuit (a) only one LED will work at a time by reversing the battery polarity, but in circuit (b) the LED will emit light alternately, as the electric current changes direction at the operating frequency of the generator. This will give no doubt concerning the role of the LED in an electric circuit and the identification of electric current direction.

At the end of this activity, we expect students are able to do a critical analysis regarding the direction of the electric current in electric circuits. It is also a good practice to invite students to summarize their conclusions in the form of a knowledge Vee heuristic mapping [9] and/or a concept mapping [10-11]. Work is in progress for implementing this experimental approach with K-9 level students from Brazil and Portugal.

3. Conclusions

The need to diversify teaching strategies to counter school failure can facilitate teaching and stimulate learning. In this perspective, the experimental work is very useful to enhance students' meaningful learning, as well as to remedy misconceptions in physics.

The experimental activity proposed for an early stage of instruction, shows that a lamp is an element of the electric circuit that has no polarity and thus conducts electric current in any direction. However, a LED has polarity, identified physically by terminals with different lengths, driving the electric current from the direction of the positive terminal to the negative terminal, but not in the opposite direction. For this reason, a LED conducts the electric current in only one direction.

Therefore, by using a simple experimental inquiry-based approach such as the one described, we expect that at the end of the activity students will be able to discuss and

understand the direction of the electric current in different electric circuits, not only those involving electrons, but also for other type of charge carriers (e.g., ions). The final goal is when they are asked to response to the challenging question of the activity, they are able to discuss with their colleagues, and to arrive at a response that looks scientifically coherent. We believe that working this topic in fundamental instruction is a good choice for preventing misconceptions in the future.

4. References

[1] Young, H.D., Freedman, R.A. (1996). *University Physics*, 9th edition, New York: Addison-Wesley.

[2] Serway, R.A., Beichner, R.J. (2000). *Physics for Scientists and Engineers with modern physics*, 5th edition, Orlando, FL: Saundrs College Publishing.

[3] Direção-Geral da Educação, Metas Curriculares do 3º Ciclo do Ensino Básico – Ciências Físico-Químicas. Disponível em: http://www.dge.mec.pt/sites/default/files/ficheiros/eb_cfq_metas_curriculares_3c_0.pdf . Acedido em 15/05/2018.

[4] White, R. T., & Gunstone, R. F. (1992). *Probing Understanding*. Great Britain: Falmer Press.

[5] Bruner, J. (1971). *Toward a theory of instruction*. Cambridge, MA: Harvard University Press.

[6] Arons, A.B. (1997). *Teaching Introductory Physics*. John Wiley & Sons, Inc., New York.

[7] Vigotsky, L.S. (1978). *Mind in Society - The Development of Higher Psychological Processes*. Cambridge MA: Harvard University Press.

[8] Ausubel, D.P. (1963). *The Psychology of Meaningful Verbal Learning*. New York: Grune and Stratton.

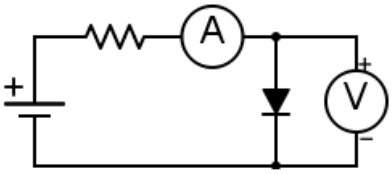
[9] Gowin, D.B. (1981). *Educating*. Ithaca, NY: Cornell University Press.

[10] Novak, J.D., Gowin, D.B. (1984). *Learning How to Learn*. Cambridge, MA: Cambridge University Press.

[11] Novak, J.D., Gowin, D.B., Johansen, G.T. (1983). The Use of Concept Mapping and Knowledge Vee Mapping with Junior High School Science Students. *Science Education*, 67(5), 625-645.

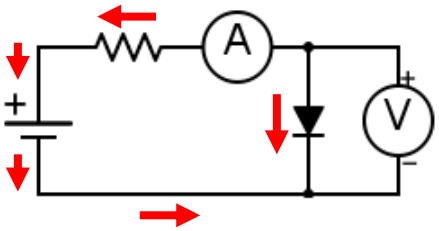
5. Appendix A

The electrical circuit of the figure, constituted by a DC power supply, a resistance, a diode, an ammeter and a voltmeter, has a flow of electric current.

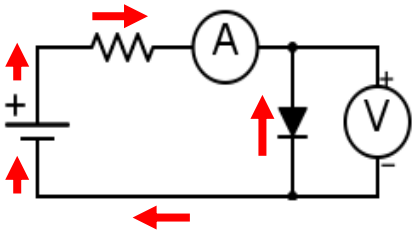


Indicate which of the situations correctly represents the **direction of the electric current** (represented by arrows) in the various parts of the circuit.

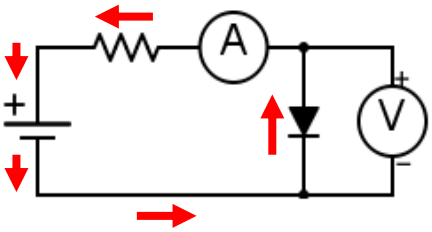
(a)



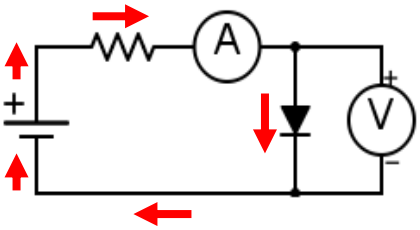
(b)



(c)



(d)



(e)