Acquiring Knowledge in Learning Concepts from Electrical Circuits: The Use of Multiple Representations in Technology-Based Learning Environments

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ABSTRACT

The constructivists approach on the conception of relative software of modelling to training and teaching of the concepts of current and voltage requires appraisal of several disciplinary fields in order to provide to the learners a training adapted to their representations. Thus, this approach requires the researchers to have adequate knowledge or skills in data processing, didactics and science content. In this regard, several researches underline that the acquisition of basic concepts that span a field of a given knowledge, must take into account the student and the scientific representations. The present research appears in this perspective, and aims to present the interactive computer environments that take into account the students (secondary and college) and scientific representations related to simple electric circuits. These computer environments will help the students to analyze the functions of the electric circuits adequately.

Keywords: Electric circuit, student representation, simulation, interactive, environment

1. INTRODUCTION AND PROBLEMATIC

The theory of electric circuits indicates that all phenomena are interpreted in terms of the concepts of current and voltage. Based on a research survey in different countries with pupils of 8 to 20 years old, the lack of adequate knowledge on the concepts of current and voltage has clearly emerged as one of the major difficulties [1, 2, 3, 4, 5]. For example, in a research involving high school students and their teachers, Cohen, Eylon and Ganiel [6] concluded that the teachers, all of whom had a degree in physics, experienced major difficulties with voltage and the intensity of current. Fredette and Lochhead [7] proposed simple experimental situations, and observed that some university students refer to a unipolar model when asked to light a bulb using wires and a battery. These students believe that, since current flows from the battery to the light bulb, the return conductor is unused and therefore superfluous. Finally Métioui and Levasseur [5] have conducted research involving students (ages 17-20) enrolled in electrical engineering technology programs in Québec. Their results indicate that the students' representations of current and voltage are erroneous. In order to correct this situation, some researchers emphasized the importance of instruction in order to acquire a better understanding of the concepts of current and voltage; especially by using various analogies [8, 9, 10, 11]. However, most authors agree that we must be careful on using analogies in order to facilitate the acquisition of the concepts of current and voltage. For example, in the "hydraulic model", where the pressure of the liquid is analogous to the voltage and the debit to the current, the student doesn't necessarily have the relative adequate knowledge of the concepts of pressure and debit [10, 12, 13].

The development of learning environments that aims to change student's representations of electric current and voltage are based mainly on artificial intelligence and make use of the different mental, qualitative and quantitative models, relative to the electric circuits ([14, 15]. Also, one develops more and more innovative software to simulate electric circuits [16, 17]. For example, Berube [17] published an innovative simulated laboratory in order to:

> "[…] helps students learn and understand circuit analysis concepts by using Electronic Workbench software to simulate actual laboratory experiments on a computer. [In that students] work with circuits drawn on the computer screen and with simulated instruments that act like actual laboratory instruments. Circuits can be modified easily with on-screen editing, and the results of analysis provide fast, accurate feedback. [Its] "Hands-on" approach throughout - in both interactive experiments associated with a series of questions about the results of each experiment - is more cost effective, safer, and more thorough and efficient than hardwired experiments. This lab can be sold for use with any DC/AC text."

Thus, the students can conduct an experiment easily and complete some circuits in relatively short time while they are confronted to solve non canonical problems. In spite of the irrefutable contribution of the software environment, it's rarely taken into account the systematic approach of the students towards the erroneous knowledge, which are extensively discussed in the literature review [5]. Many researcher underlines the reasons why the students representations is not taken into account, which will help to reconstruct the models underlying the difficulties associated with electric circuits [5, 18]. Our research appears in this perspective and aims to the conception of computer environments for the teaching of the electric circuits. Such environments must take into account the multiple representations of the students, as well as the relevant scientific concepts. This approach is inspired by current conceptual change approaches which state that students' representations can be improved through conceptual conflicts.

2. PROGRESS OF THE STRATEGY PROPOSED

The conception of the computer environment that helps students model the electrical properties of circuits takes place in five steps as illustrated in Figure 1. We present in the next section the objectives pursued in each step.

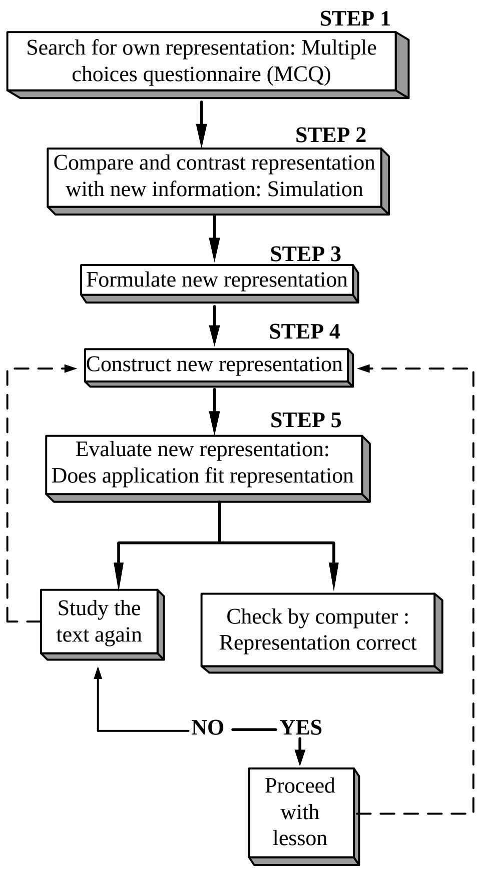


Figure 1: The steps of the software

2.1. Step 1: Search own presentation: Multiple choices questionnaire (MCQ)

Constructivism learning has inspired international studies on the student's representations with regard to the properties of electric circuits which were the subject of numerous publications [5, 19, 20, 21, 22, 23]. With respect to this topic, Rozencwajg [24] underlines that the didactics of electricity allows us to construct application problems and a grid of analysis of their resolution provided that we know the students' representations. Let's underline that traditional teaching this approach is difficult, or even impossible (1) to implement this approach since, it requires to present to students all the situations that may involve their representations, the number of those identified by research is large and (2) to take account implement this approach since it requires the multiple representations of the students that can vary from a one to another. In this perspective, a computer environment will allow to cover the whole with the problems identified in the research and will allow to every student to work according to his rhythm. To this topic, de Jong et al. [25] underline the necessity to develop strategies using multiple technologies to encourage learners to construct their own knowledge: “Constructivism is supported by computer environments such as hypertexts, concept mapping, simulation and modeling tools” (p. 9). In this step, the student will be invited to complete a multiple choices questionnaire (MCQ). To each question, the student has to pick up the answer, among the ones proposed, that most closely reflects his actual understanding of the phenomena described in the question and has to justify his choice in the space provided. The stage of justification is very important since it allows the researcher to get some insurance that the choice of the student is not unpredictable but is associated instead with its current understanding of the phenomena.

This preliminary approach has the objective to allow the student to specify his representations on the topic. Some examples of the situations investigated in the questionnaire are presented below.

Situation 2.1.1: Many researchers has demonstrated that the majority of the pupils of primary schools refer to “unipolar model” when asked to power a light bulb using wires and battery [26]. These students reason that current flows from the battery to the bulb as shown in figure 2. The return wire is considered useless and passive. This false model persists in the discourse of students after formal teaching [1, 27].

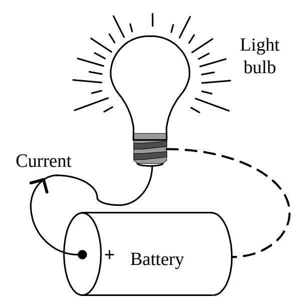


Figure 2: Unipolar model

The purpose of the present situation is to verify if for the student, all the three light bulbs (A, B and C) illustrated in diagram 1 are equally lit, because electrical current flows through every wire.

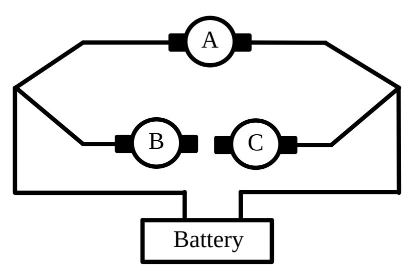


Diagram 1

Choose the answer that you think is correct:

- ☐ The bulb A is going to shine more because it receives a bigger quantity of electricity (two wires) while B and C receive less (1 wire).
- ☐ The bulbs B and C shine normally because they are placed symmetrically in the circuit. The bulb A will shine differently because it going to receive different current.
- ☐ None of these answers.

Explain your choice.

Situation 2.1.2: The objective of the problem illustrated below is to verify if the student is inclined to refer to the 'attenuation model'. According to this model, in a circuit constituted by a battery and a bulb, the current leaves the battery from one end, is partly dissipated in the bulb, its unused portion returning to the battery as illustrated in figure 3.

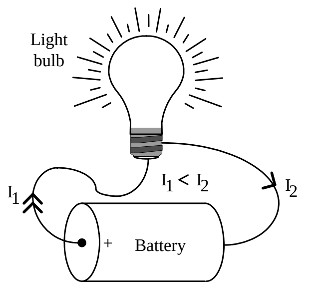


Figure 3: Attenuation model

Many researches demonstrate that this erroneous model persists among the students even after teaching [5]. The solution of this problem requires the principle of conservation of the charge and the acquisition of the concepts of 'current' and 'voltage'.

In diagram 2, bulb (A) shines normally, bulb (B) shines dimmer and bulb (C) doesn't shine. If the positions of bulbs A, B and C are changed as illustrated in electric diagram 3, will their brightness change too?

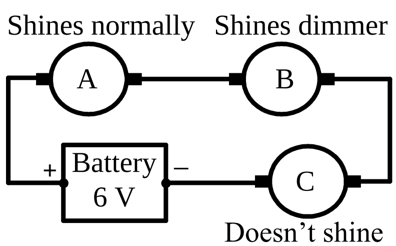


Diagram 2

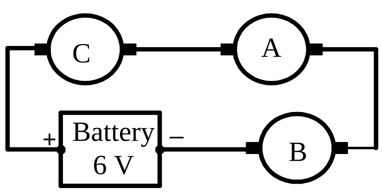


Diagram 3

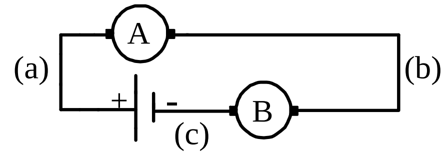
Choose the answer that you think is correct:

- ☐ Bulb C will shine normally, bulb A will be dimmer and bulb B won't light; because the bulb that is closer to the power supply receives more electricity than those situated further (considering the direction of current from + to -).
- ☐ If in the first diagram bulb C doesn't shine, it is deficient. Thus, no matter where the bulb is placed it won't shine. Besides, if bulb C is placed near the power supply, the other bulbs won't light because the current won't pass through any of the other bulbs (circuit in series).
- ☐ The brightness is proportional to the number of watts in which a bulb will need to light normally. If the circuit supplies a bulb with 60 watts, the bulb of 100 watts will be dimmer and the one of 25 watts will burn.
- ☐ None of these answers.

Explain your choice.

Situation 2.1.3: The following problem requires the same knowledge that the previous problem to solve it. Let's note that we put an accent on the length of the electric wires.

In the diagram 4, bulb A shines normally and bulb B shines dimmer.



Electric wire (a): 10 cm
Electric wire (b): 2 m
Electric wire (c): 3 cm

Diagram 4

Choose the answer that you think is correct:

- ☐ The electric current circulates of it from the positive (+) to the negative (-) poles. Since the bulb A is met first in the circuit when one follows the direction of the electric current, it illuminates more that the bulb B because the intensity of electricity is stronger at the beginning of the circuit. Thereafter, it loses the intensity toward the end of the circuit.
- ☐ In fact, the longer the electric wire, the longer the path the electric charges have to travel before reaching the light and therefore the smaller the intensity of the current is. In reality, the current goes in one direction: it leaves the battery, goes toward the bulb and makes a long journey toward B. It is for this reason that the light B shines less that light A.

Explain your choice.

Situation 2.1.4: To solve the following problem, it would be necessary to know the notion of 'closed' circuit. Thus, when a component is damaged in a circuit, the circuit becomes 'open'.

In the diagram 5, the three bulbs have the same brightness.

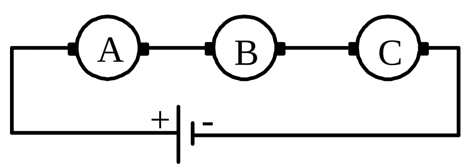


Diagram 5

If one of them burns, what do you think of the following sentences?

- If one of the bulbs burns, the energy that it used is then transmitted to the other two bulbs. If one of the bulbs burns, the other ones continue to shine because there is always current in the circuit.

  ☐ True ☐ False

Explain your choice.

- The electric current always circulates. It is the filament of the bulb A that is affected:

  ☐ True ☐ False

Explain your choice.

- The electric current circulates in the basis of the burnt bulb, therefore the B bulbs and C will normally illuminate:

  ☐ True ☐ False

Explain your choice.

Situation 2.1.5: The objective of this situation is to verify as in the precedent situation, the student's capacity to use the notion of close circuit. It is about a situation that frequently occurs when we push on a switch to make operate a lamp.

In the diagram 6, the switch is in position "on", but the filament of the lamp is "grilled".

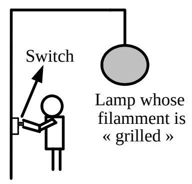


Diagram 6

Choose the answer that you think is correct:

- ☐ Electricity is a movement of electrons. If one puts the switch in position "on", the movement of the electrons is going to take place, but it won't be able to go until the filament of the lamp because it is broken.
- ☐ So that some current circulates, the circuit must be closed. However, if the bulb is grilled, the circuit is open and the current doesn't circulate.
- ☐ If one doesn't put the switch in position stop when one changes the bulb, one can receive a shock. The electric current surrenders therefore all the same.
- ☐ None of these answers

Explain your choice.

Situation 2.1.6: Many researchers established that the majority of the primary students refer to ‘clashing currents model’ when asked to power a light bulb using wires and battery [23]. These student reason that the currents flowing towards the light bulb from each battery terminal collide and produce the observe phenomenon as shown in figure 4.

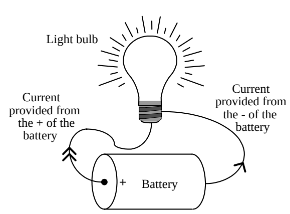


Figure 4: Clashing current model

Benseghir and Closset [28] demonstrate that this erroneous model persists in spite of teaching electrical circuits on several years. According to these authors, this false model results from an inappropriate transition from the principle concepts of the electrostatics to the concepts of the electrodynamics. It's also due to an inappropriate assimilation of the principle working of the battery.

The present situation has for object to verify if the student will refer to the ‘clashing currents model’. In the diagrams 7 and 8, the bulbs A and B are identical.

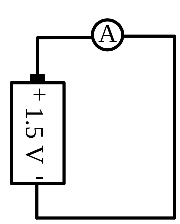


Diagram 7

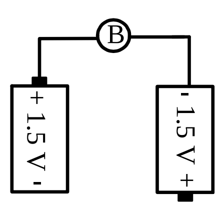


Diagram 8

How will the lighting of every bulb be? Choose the answer that you think is correct:

- ☐ Bulb B will illuminate twice more than bulb A, because the intensity of the current in diagram 7 is two times stronger than the one in diagram 1 since the voltage is doubled.
- ☐ The two bulbs are connected to a boundary-mark (+) and a boundary-mark (-). Since the voltage of the batteries is the same, the two bulbs should also shine.
- ☐ Since two batteries provide more energy than one only, the intensity of the electric current in the diagram 2 will be bigger, and bulb B will shine more strongly.
- ☐ Bulb B is going to shine more than bulb A, because the electric wire of diagram 2 is smaller. The smaller the wires, the higher current passes through.
- ☐ The two bulbs will shine *as much*, because even though there is another battery in B, the current cannot leave from the negative boundary-mark to the positive boundary-mark. This battery is therefore useless.
- ☐ None of these answers

Explain your choice.

2.2. Step 2: Compare and contrast representation with new information (simulation)

In the present step, the student will have to compose on screen the circuits presented in the previous step and to simulate their working. This important step has for objective to create a conceptual conflict for the student who will be made aware of the difference between some of his anticipated answers and the results of the simulations. Let's note that this destabilization of the student's conceptual system won't bring him to abandon false representations because they are anchored in his cognitive structure. Berti [29] underline what follows to this topic:

> “It has been frequently observed that students, independently of their age, are very reluctant to abandon their physical misconceptions: most never acquire or misinterpret scientific notions taught in class, or revert to pre-instructional conceptions after leaving school […]. When a change occurs, it takes a long time […]. Three main kinds of cognitive explanations for resistance to change have been put forward […].” (p. 116)

2.3 Step 3: Formulate new representation

Indeed, the system of representations of the student is extremely steady and resists to the "contradictions". Even the most obvious physical experiences are not sufficient to disrupt the beliefs of the student [30, 31]. Thus, it goes without saying that the student will not be able to abandon his representations, but he will be made aware of their shortcomings. For example, all modification introduced in a circuit will affect its working. Therefore, while introducing an electrical resistance into a circuit, the lighting of the bulbs will be varied. In some simple situations, the student will be brought to identify the function responsible for this disruption state, without explaining what it is produced necessarily.

2.4 Step 4: Construct new representation-Proceed with lesson

Results of research in many countries show that the majority of conceptual difficulties encountered by students about the theory of electric circuits originate from their false representations of current and voltage. Consistent with these findings, Rohrer [32] challenged the traditional approach of teaching circuits theory.

He expressed a deep concern in the following terms:

> "No, today's electronic reality is not resistors, inductors and capacitors. It is black boxes full of black boxes. … Much of the problem lies with the abilities and attitudes of today's students. But much of the problem lies too, with what we are trying to teach in the introductory circuit course. I am not advocating that we pander to students and water down the introductory circuit course. We've already done that. What I do advocate for openers is that we reevaluate the present course with respect to our main goals as circuit and systems engineers: to explain the interrelationships among circuit concepts, and to provide students with an understanding of the fields as a cohesive set of basic principles from which many useful results can be deduced."

Our research appears in this perspective and aims to the conception of computer environments for the teaching of the electric circuits. Such environments must take into account the representations of the students, as well as the relevant scientific concepts. This approach is inspired by current conceptual change approaches which state that students' representations can be improved through conceptual conflicts [3].

Below is the proposed gait to initiate the students to the modelling of simple electric circuits according to the systemic approach.

2.4.1 Systemic approach to the theory of electrical circuits

The development of semiconductors science started in the sixties of the XX[th] century, and allowed the scientists to design and test a wide range of electronic components such as: resistors, capacitors, transistors, diodes, etc. Accordingly, engineers have used these electronic components to construct and develop more sophisticated electronic devices and systems. These inventions questioned the traditional approach of electrical and electronic circuits in favor of the systemic view of electrical and electronic circuits [32, 33, 34, 35, 36]. With these authors, we consider the systemic approach as a scientific modelling of the systems under study, leading to a constructivist approach to electrical theory circuit. The following characteristics, which contrast with the traditional approach, are considered as indicative of a systemic approach:

1) No essential distinction is made between components and circuits. Black boxes are used consistently, for a single resistor to the most complex circuit, and the characterization process is considered as fundamental.

2) Models are distinguished explicitly from physical devices. The model is the primary reference; the component or circuit is considered as an imperfect implementation of the model, instead of the model being an approximate description of the physical component.

3) The conducting network, which carries signals and power, is more valued than the components. Currents are defined in conductors (and extended to branches), while voltages are attributes of pairs of points (extending to pairs of nodes). Currents and voltages are only indirectly associated with component terminals.

4) Circuit analyses and circuit synthesis are valued equally in the learning process.

5) The physics of components is clearly distinguished from circuit theory: it is dealt with as the need arises.

Concepts related to electrical circuit theory can be divided into two distinct categories: the first category concerns circuit topology and Kirchhoff's laws, and deals with the transmission of signal and power in the conducting network. The second category addresses the characterization of devices (modelling them, or establishing their current/voltage relationships). These two aspects are fundamentally different in nature, and they play complementary roles in the analysis and in the synthesis of circuits. In this view of electrical circuit theory, circuit analysis and circuit synthesis become mathematical games in the manipulation of the above mentioned concepts. Engineering and physics play a role through practical considerations, and when considering deviations from models. The present trend, in the electronics industry, is to encapsulate most second-order effects within commercially available components; as a result, modern circuit analysis and circuit synthesis tend to involve more mathematics and less physics. The figure 5 synthesizes the conceptual structure of the electric circuits in the systemic approach described above.

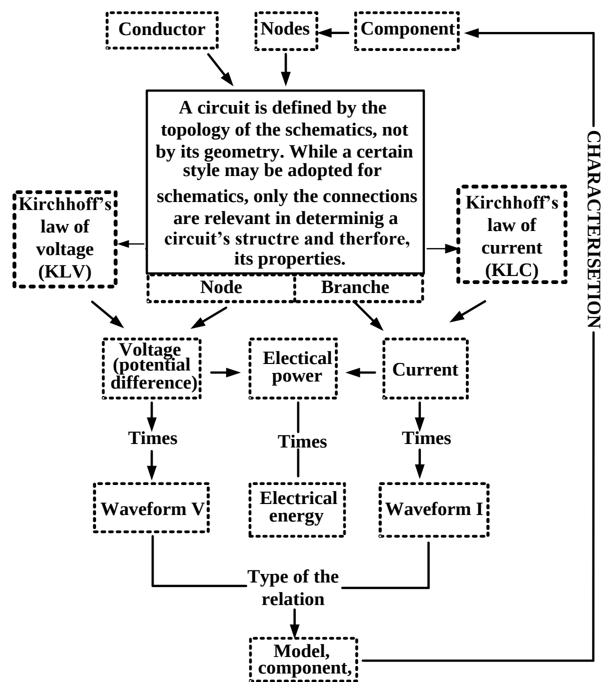


Figure 5: Conceptual structure of Electrical circuits in the systemic approach

Let's note that the use of the systemic approach does not decrease the importance of eventually understanding the physics of component, such as semiconductor physics. The need remains. What it does accomplish, however, is a decoupling of this need from the problem of learning circuit theory. Also, because the abstract models of the systemic method are rooted in mathematics, they are applicable to all branches of science and engineering. It is in the ensuing transferability that precious learning time can be saved, not in the elimination of the teaching of the underlying physics principles.

2.4.2 Initiations to the electrical network and Kirchhoff's laws

First able, the student will acquire the understanding of the networks, branches and nodes, as well as the Kirchhoff's laws. At this stage, it's very important that the student understands that an electric circuit is constituted of drivers defining a network of nodes and branches of components defining a network of nodes and branches, each of which contains a set of functions joining the nodes between them. Every function contributes to establish equilibrium of the currents and the voltages of the whole system [37]. It's also very important that the student knows how to measure the current with an ammeter and the voltage with a voltmeter. In summary, the student must understand that:

1) Current is defined in a conductor and, by extension, applies to the whole branch.
2) Voltage across the terminals of a component is defined between the two terminals.
3) Mesh analysis is limited to linear circuits; it is a mathematical algorithm using fictitious partial currents.
4) Potentials are static. They evolve with time, but they do not move around. Within the framework of circuit theory, potentials are defined only on conductors and on the terminals of components.
5) To measure the voltage between two nodes, we must plug the voltmeter between these two nodes, the common boundary-mark on the node reference.
6) To measure the current in a branch, we must insert the ammeter anywhere in the branch, the common boundary-mark on the side of the end of the branch.

2.4.3 Modelling simple electric circuits

The studies carrying on the instruction to the steps of modelling of the electric circuits are in the beginning. In this step we will see it is possible to provide the student a conceptual setting allowing him to participate actively in the process of modelling of a simple electric system. We present below the conception of computer environments simulation various the experimental situations that help the students to characterize and model the concepts of electric circuits to two boundary-marks: the resistance, and current and voltage sources. The environments below only constitute an example of the types of modelling and don't pretend to cover the entire subject.

Thus, he will be brought to study a system in equilibrium described by four unknown functions schematized there by four black boxes W, X, Y and Z (diagram 9).

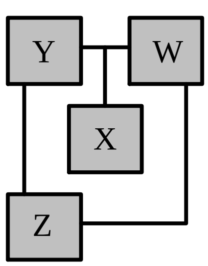


Diagram 9: Simple electrical system

When the equilibrium is modified, it is necessary to ask the student to measure the new state that results from this disruption with the help of measurement devices of the electrical quantities involved. Afterward, the student will be invited to indicate the function responsible for such a state. He will owe modules each of the functions while bringing it back in a characterization environment (diagram 10) to impose some variables of state in order to observe its behavior. In this stage, the student will be sensitized to the existence of the devices (ammeter and voltmeter) permitting the measure of the intensity of the electric current (I) and the voltage (U).

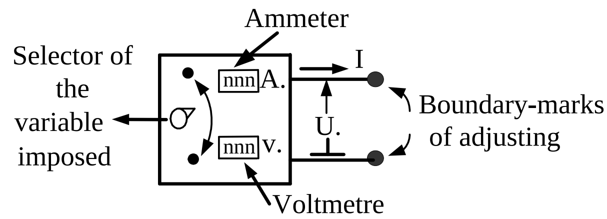


Diagram 10: Device of characterization of the current (I) and the voltage (U)

The use of these devices constitutes an element essential to a first tentative modelling of the system in question. Indeed, the measurement processes allow the student to design situations in the virtual laboratory adequately that helps him conceive a suitable model. When this process of measure is interpreted well, the student has the possibility to establish a correspondence between the situation of laboratory and the suitable model.

2.4.3.1 Modelling of black box X: The modelling of the black box X will take place while bringing it back to its environment of characterization, as illustrated in diagram 11. In this case, the student can impose the values of U or I.

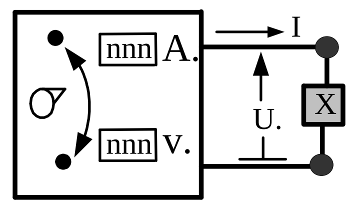


Diagram 11: Characterisation of the X function

The cursors move following the oblique trajectories and the reference marked on the axis of the variable non manipulated moves to illustrate that in this case, U and I are bound between them. Once he will note that U and I are bound between them according to the graphs schematized to diagram 12, the software will remind him that all function having this behavior would be identified by the symbol illustrated in diagram 13 and would carry the name of resistance that is noted by symbol R and expressed in ohm (Ω).

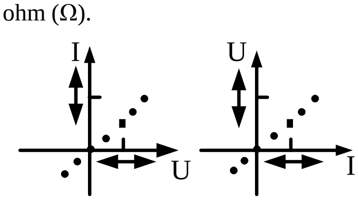


Diagram 12: Graphs of the functions [U = f(I) and I = f(U)]

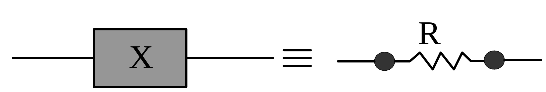


Diagram 13: Resistor symbol

2.4.3.2 Modelling of black box Y: In the case of black box Y, the student will get the same results that in the case of the modelling of box X. He will observe a linear relation between the intensity of the electric current and the voltage, and he should conclude that it is about resistor element. It is important that the student assimilates that the resistor component displays a curve in the graph voltage instantaneous /current instantaneous that is the same for all shapes of waves in a given application. One cannot infer the behavior of a component on the basis of one instantaneous value of the intensity of the current and the voltage. Unfortunately, this conceptual representation is not shared by the majority of students having followed a formal teaching on the topic [2]. The conceptual representation is commonly accepted by the students of the collegiate who are registered in the technologies of electricity (1st, 2nd and 3rd years) consists in calculating a resistance while dividing voltage by the current, in accordance with the law of ohm.

Thus, according to the majority of the students interviewed, two components that have the same voltage and current are in the same way resistance "interchangeable", even though they are of different nature. In a synthesis study on the teaching of Ohm's law, the authors stated:

> "[…] college students in Québec experience considerable difficulties in determining the conditions of applicability of Ohm's law to simple circuit. These students view Ohm's law as universally applicable, literally as the cornerstone of circuit theory. […] the traditional approach to circuit theory leads to major difficulties with the applicability criteria of Ohm's law. This predicament, which persists after five semesters of formal education in electronics, is apparently rooted in inadequate conceptions of voltage and of current." (p. 209)

2.4.3.3 Modelling of box Z: The modelling of box Z will take place according to the experimental device of diagram 14 and one will get the results illustrated to the diagram 15.

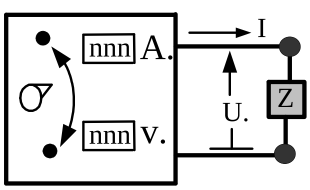


Diagram 14: Characterization of the Z function

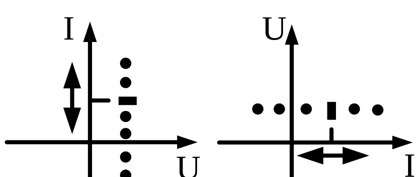


Diagram 15: Graphs of the functions
[U = f(I) and I = f(U)]

In this case, the student manipulates the intensity of the electric current I and observe the successive displacements of the cursor. Here, all manipulation of U will bring a particular behavior of the display to really illustrate the infinities and the indeterminations. Once the student observe that U and I are bound, the software will make him note that all function having this behavior will be represented by the symbol illustrated to the diagram 16 and will carry the name of the source of tension.

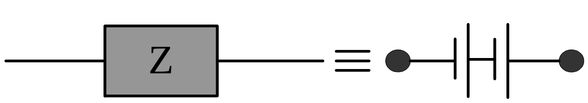


Diagram 16: Voltage source symbol

2.4.3.4 Modeling of box W: In order to model box W, the pupil will have to design the experimental device shown in figure 17.

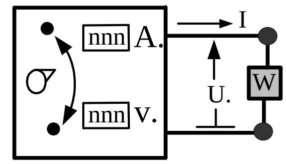


Diagram 17: Characterization of the W function

The experiment consists of applying values of the electric current and measure the voltage, and vice versa. The immediate values are displayed numerically on the device of characterization and the historic of the experience will be consigned on two diagrams presented in diagram 18.

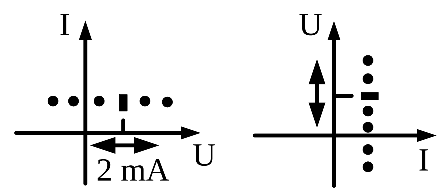


Diagram 18: Graphs of the functions
U = f(I) and I = f(U)

The fact to have two orthogonal diagrams between them will guide him to discern the behavior of a simple horizontal or vertical line, and will facilitate his initiation to the current-voltage duality. In the case where the student will impose an intensity of the electric current, the voltage will stretch toward the infinity and the intensity of the current will be indeterminate. These complex phenomena for the student will be illustrated by the displacement of the cursor to the maximum position on the axis of voltages. The voltmeter will display the OVL message and the ammeter, changing value of the electric current. A scorer will move continually on the axis of the intensities of the electric current (▬). Once the student have noted that the electric current, browsing black box W, is constant, the imposed voltage, the software will notify him that all function having this behavior will be identified by the symbol illustrated to the diagram 19 and will carry the name of "current source."

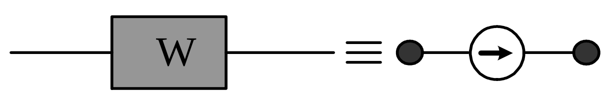


Diagram 19: Current source symbol

It is important that the student assimilates the current source, whatever the voltage is at the boundary-marks is. Such a function cannot be filled by any electric resistance. It is as important the student knows that the current source is as fundamental as the voltage source for the analysis of circuits.

2.5 Step 5: Evaluative new representation

In this step, the student will be invited to solve, qualitatively and quantitatively, a certain number of situations that requires the understanding of the models that underlines the conditions and the limitations of their uses as well as a familiarization with the modelling of electric components as studied above.

Situation 2.5.1: The purpose of this situation is to verify if the student is inclined to replace systematically, an unknown component, by 'its equivalent resistance'. The solution of the problem requires the comprehension of the model that underlies a resistor element, as illustrated below.

According to the diagram 20 below, the unknown component X doesn't represent a resistor:

☐ True ☐ False

Explain your choice.

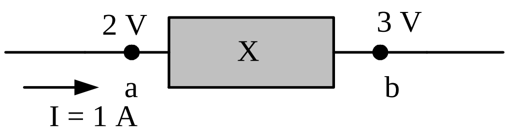


Diagram 20

According to the data of this problem, one cannot decide the exact nature of this component, except to rule out components which cannot output electrical power, such as resistors, diodes or light bulbs. Indeed, the intensity of the electric current of 1 A "cowl" of the potential of 2 V to a potential of 3 V, the component X produces a power of 1 W; one cannot decide its exact nature, except to rule out components which cannot output electrical power, such as light bulbs, diodes or resistors. Métioui, Brassard, Levasseur and Lavoie [2] demonstrate that the majority of the students of the technical college associate an unknown component spontaneously to a resistance while applying Ohm's Law. This generalization among the students results, because during their formation, one didn't insist sufficiently on the limits of applicability of this law:

> […], we know from their normal schoolwork that they are perfectly capable of applying Ohm's law to a resistor lying on the bench. Yet, they appear to experience serious difficulties with the simplest unusual circuit situation. The basic topological concepts of nodes and branches (circuit structure), which support voltage and current, appear to be severely lacking [2].

Situation 2.5.2: This situation was intended to determine this time whether student is conscious of the impact of a non-linear element on the whole circuit.

The current of lamp LP1 is given graphically (diagram 21), as a function of the voltage across the lamp. In the situation depicted in the schematic (diagram 22), the current in LP1 and in R are both equal to 4 amperes.

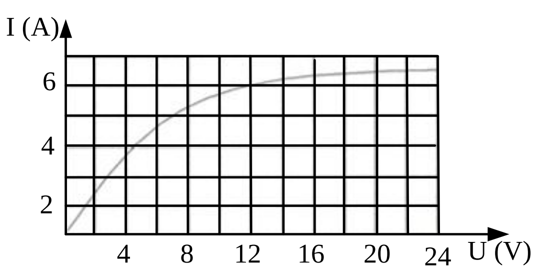


Diagram 21

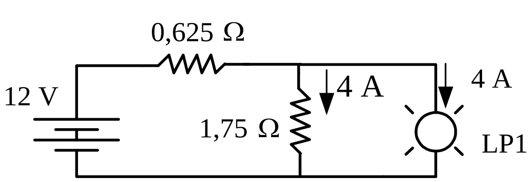


Diagram 22

If the 12 volt source is replaced by a 24 volt source, the two currents remain equal to each other because: « In a parallel circuit, the voltage is equal; the currents are also equal, therefore the bulb LP1 and the 1.75Ω resistor are equivalent. If V and R are constant, I will be also. »

☐ True ☐ Wrong

Explain your choice.

Situation 2.5.3: The purpose of this situation is to verify the ability of student to use adequately the model of the current source. Let's recall that the source of current determines the current in the branch where it is situated.

According to the data illustrated in the diagram 23 below, choose the answer that you think is correct:

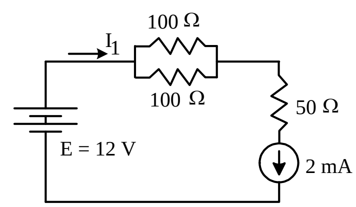


Diagram 23

- ☐ The intensity of I_1 is equal to 120 mA, *because I_1 is equal to E (12 V)* across R (100 Ω: 100 Ω in parallel with 100 Ω, which is equivalent to 50 Ω; in series with 50 Ω that makes the total resistance equals to 100 Ω).
- ☐ If the battery is reversed, the intensity of I_1 will be equal to 118 mA, because the current changes sense and it is going to juxtapose itself with the source of current of 2 mA that it would be necessary to subtract the 120 mA.
- ☐ If one doubles the voltage, the intensity of I_1 will be two times bigger because the resistance is two times smaller.
- ☐ If one doubles the resistance of 50 Ω, the intensity of I_1 should be smaller, because the resistance is doubled.
- ☐ If one doubles the resistance of 50 Ω, the intensity of I_1 should increase, because the resistance is decreased.
- ☐ None of these answers.

Explain your choice.

Having already assimilated the model of the current source, the student will deduct in the case of diagram 22 that the intensity of the electric current asked remained the one of the current source (2 mA). This situation allowed Lavoie, Métioui, Levasseur and Brassard [34] to put in evidence a false representation among students that the authors named the model of the "freeway" and that permits to several electric currents different to cohabit in a same "driver" as illustrate in figure 6. Thus, the majority of the students interrogated added merely the 2 mA produced by the current source to the one that would be produced by the voltage source, calculated while applying Ohm's law.

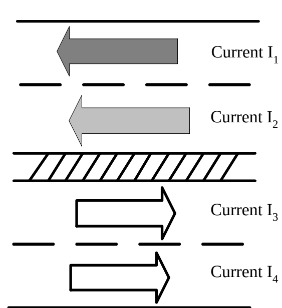


Figure 6: The freeway model

Situation 2.5.4: The objective of the following problem is verifying the assimilation by the student of the notion of the source of ideal current. Indeed, the student must note that there is not any change on V_c since the current in the C_1 capacitor won't be affected; the source of ideal current provides the same current, whatever is the value of the serial resistance.

According to the data illustrated in the diagram 24 below:

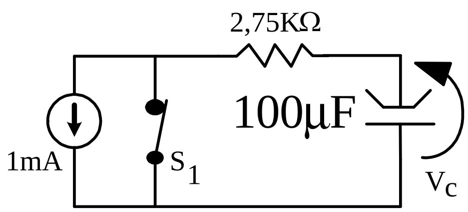


Diagram 24

One opens the S_1 switch that was previously closed during one minute. The V_c tension evolves in a certain manner. If one redoes the same experience with the resistance of 5,5KΩ, the V_c tension won't be modified since the current in the C_1 capacitor won't be affected:

☐ True ☐ False

Explain your choice.

Situation 2.5.5: The goal of this situation is to verify as in the previous situation, the student's capacity to use the model of the current source adequately. In this case, we want to verify if the student is conscious that a battery doesn't produce the same current if the circuit in which it is affected. Let's note that for many students, when a circuit composed of a battery and resistors is modified, the current supplied by the battery remains unchanged [5, 37].

In diagram 25, bulb (A) shines normally, bulb (B) shines dimmer and bulb (C) doesn't shine. The battery produces a current of 0,3 A.

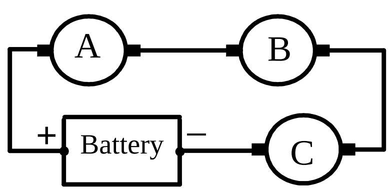


Diagram 25

If one short-circuits the C bulb with an electric wire (diagram 26), the current produced by the battery would be:

☐ Lower than 0, 3 A
☐ Superior than 0, 3 A
☐ Equal to 0, 3 A

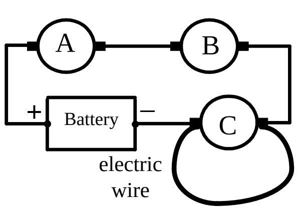


Diagram 26

Choose the answer that you think is correct:

☐ In a series circuit the current is the same for every point of the circuit. Besides, the C bulb doesn't shine; to short-circuit it doesn't change anything in the produced current by the battery.
☐ The current cannot be the same because the circuit becomes completely different since the C bulb is short-circuited. One cannot know the intensity of the current.
☐ If one short-circuits the C bulb in a series circuit, one has an overvoltage. Indeed, the electrons will go more quickly since there is a resistance of less. Therefore, the current Will be superior to 0,3 A.
☐ Even though one short-circuits the C bulb, the current produced by the battery will always be the same (0,3 A) except that the bulbs A and B will have each 0,15 A because the bulb C doesn't offer any resistance. In this case, the bulbs A and B win the current.
☐ None of these answers.

Explain your choice.

Situation 2.5.6: This situation was intended to verify if the student is able to compare the functionality of a series circuit and a parallel circuit on referring to the current and voltage sources.

In the diagram 27, the bulbs A and B are connected to the 6 V battery and they have the same brightness. In the diagram 28, we connected two bulbs A and B identical to those of the diagram 27 as illustrated:

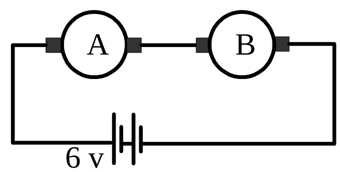


Diagram 27

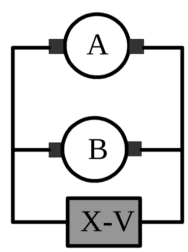


Diagram 28

We want that these two bulbs have the same brightness as in circuit 1. For it, one must use X-V battery:

☐ Equal to 6 V
☐ Superior than 6 V
☐ Lower than 6 V

Choose the answer that you think is correct:

☐ In the circuit series 1, the 6-V battery provides 3 V across each bulb. In the circuit parallel 2, the X-V battery provides X-V across each bulb. So that to have the same brightness in the two circuits, it's necessary to have 3-V battery.
☐ Since the circuit 2 is a parallel circuit, a 12-V battery will be necessary so that the bulbs illuminate with the same intensity that in the circuit 1.
☐ One must use a 6-V battery. But one must used a battery producing the same current and the same bulbs also that those of the circuit 1.
☐ None of these answers

Explain your choice.

Situation 2.5.7: The objective of this situation is to know if the student is conscious that the presence of a source of current in a branch determines the current in this branch.

Consider the diagram 29 below:

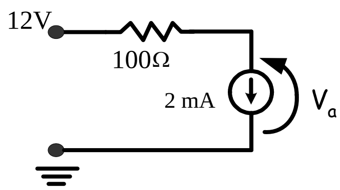


Diagram 29

In this circuit: « A source of current adds its current to the current which was already present in the branch, produced by a source of voltage. Then, the voltage V_a is equal to 0,2 V:

$$I = 12\ V/100\ \Omega = 0{,}12A = 120\ mA;$$
$$I = 120\ mA + 2\ mA = 122\ mA;$$
$$V = RI = (100\ \Omega).\ (122\ mA) = 12,\ 2\ V;$$
$$V_a = 12,\ 2\ V – 12\ V = 0,\ 2V.$$ »

☐ True ☐ Wrong

Explain your choice.

Situation 2.5.8: The purpose of this situation is to know if the student is conscious that a modification of a component in an electrical circuit affects all the circuit. Closset and Viennot [27] have found that second year university students retain naïve representations with respect to properties of electrical circuits. These authors indicate that the students' reasoning follows the current, disregarding the effect of components which they consider as downstream. In a synthesis study on this erroneous representation (called sequential model), Shipstone [1] stated:

> “The importance of this misconception is due both to its high incidence in the middle years of the 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 where training to be physics teachers.” (p.43)

Let's note that this false model probably results from the absence of a teaching the electrical circuits according to a systematic approach as described in the present article.

In the diagrams 30 and 31, the bulbs A et B are identical.

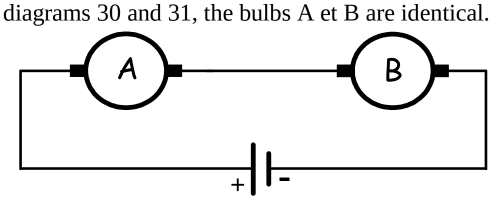


Diagram 30

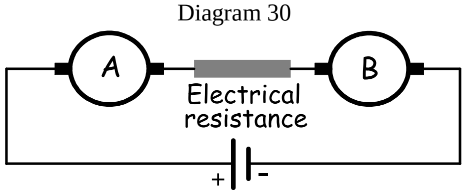


Diagram 31

What do you think of the following sentences?

- While crossing in the resistance, the current will lose the energy. The B bulb will shine less therefore.
  ☐ True ☐ False

Explain your choice.

- The brightness of the 2 bulbs will decrease since there is less current that will cross the circuit.
  ☐ True ☐ False

Explain your choice.

- The electric resistance attenuates the intensity of the current, therefore becomes less illuminated. Electricity first crosses the bulb A, and then undergoes the influence of the electric resistance. As a consequence, the rest of the current will flow in the B bulb.
  ☐ True ☐ False

Explain your choice.

8. CONCLUSION

The simulation occupies an important place in the teaching and learning approach presented here. Of course, the use of the simulation has its advantages and its inconveniences. For example, it has the inconvenience to present to the student an experimental situation where the number of variables and the way in which they interact are determined in advance in the software, creating a situation that doesn't parallel the situation of a real laboratory [38]. The application of a socio-constructivist approach recommended by several researchers is problematic since, in the case of a simulation, the student only interacts with the computer system which clearly contradicts one of the tenet of this approach, namely that interaction between peers is important to foster learning [39, 40]. In spite of this, one thinks the advantages are numerous. Among others, such an approach could engage the student in modeling his various observations about electric while taking into account his representations and his inherent learning conceptual difficulties. Let's remind us that the students’ knowledge of the concepts of current and voltage may look naïve when compared with the theory of the electric circuits, but nevertheless constitute the epistemological foundation of his reasoning with respect to the principles of simple electric circuits. The recourse to computer environments allows every student to learn according to his own rhythm and helps him to deepen his scientific notions that may provoke conceptual difficulties, even conflicts. This approach may be difficult to implement, if not impossible, in the case of a traditional teaching with big groups, where the teacher will have the difficult task to take into account the various representations expressed by students. The didactic strategy presented in this article suggests that in the conception of modelling software, one must take into account, among others aspects, the student's representations, as well the relevant scientific concepts. Otherwise, what will remain from instruction with be an illusion of having understood. As a final point, we must contend that the computer environments presented in this research don't pretend to cover the student's conceptual difficulties as listed in the review of the literature and are presented as an illustration of the various points made in this research. We intend to verify the efficacy of the proposed strategies by conducting controlled experiments with representative groups of students.

Finally, let's underline that the classic laboratory environment permits experimentation with circuits and with components. However, in the systemic approach, models are considered more important than the circuits used to implement them; therefore, the need arises for an environment supporting the direct manipulation of the models themselves. Microcomputers, when programmed to support a direct interaction of students with models, constitute promising environments.

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