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We have chosen the topic of electric circuits for various reasons: i) it is very important in scientists´, and engineers education; ii) there is evidence of rooted and widespread alternative interpretations in this field (Shipstone et al.1988) ; and iii) it seems difficult to attribute an empirical or phenomenological origin to such interpretations.
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COGNITIVE MEDIATORS AND INTERPRETATIONS OF ELECTRIC CIRCUITS

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1.INTRODUCTION.

In this work we have studied the extension, consistency and stability of the correct and alternative answers of university students´ to different questionsconcerningelectriccircuits. We also explore the utility of a theoretical constructs: "the cognitive mediators" (Viennot, 1985) in order to guide description of students´ reasonning.

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2.COGNITIVE MEDIATORS.

Viennot (1985) proposed the term "cognitive mediators" to indicate a kind of reasoning leading students to give similar answers to different questions or situations.

Such mediators would be more than just answer organizers, they also might correspond to truly functional elements of the student's mind. Fig.1 sketches the mediator functions between situation-questions and the features selected in responses (Viennot, 1985, p.157).

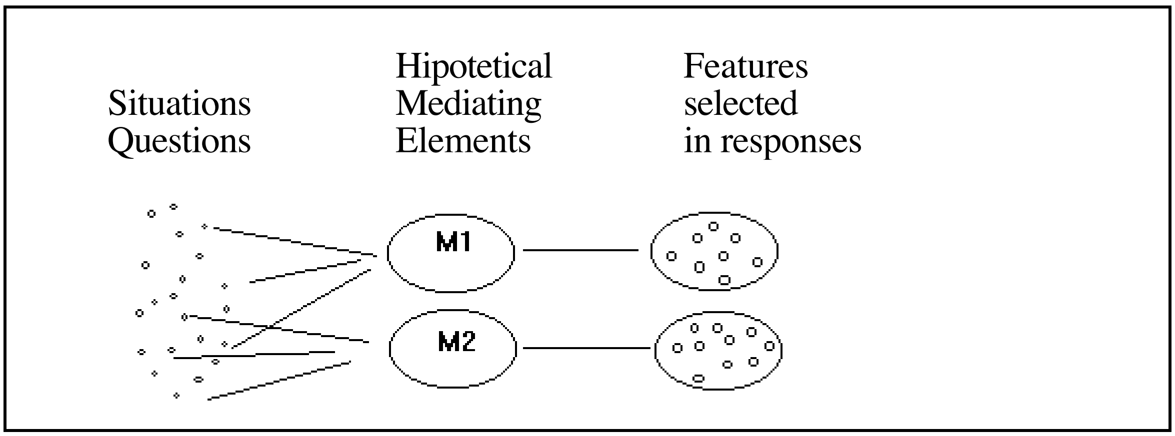


Figure 1

In this work we explore the utility of two possible mediators in alternative interpretations about electrical circuits: Mediator 1 (M1): "Sequential Reasoning", and Mediator 2 (M2): "Superposition Reasoning"

2.1 SEQUENTIAL REASONING.

Closset (1983) coined the term "Sequential Reasoning" to describe those interpretations of electric circuits allowing to infer that the variation of a given circuit component will affect only downstream events, while upstream events will remain unaltered. For example, "Sequential Reasoning lead to the conclusion that increasing resistance 'before' the bulb will result in less current in the bulb, whereas increasing the resistance 'after' the bulb will leave the current in the bulb unchanged" (Shipstone *et al*, 1988, p. 311). The incidence of the 'before' and 'after topological consideration is a key element in Sequential Reasoning characterisation. This type of reasoning is occasionally reinforced by circuit descriptions given by teachers: "the current comes out from positive pole, here it divides, then..." Under the term Sequential Reasoning we have included all circuit interpretations made "step by step", as opposed to those interpretations regarding the circuit as a system of interconnected parts mutually influenced.

2.2 SUPERPOSITION REASONING.

Analyzing the understanding of heat and temperature concepts, Strauss & Stavy (1983) have found that, for those cases in which water at 10 ^{o}C is mixed with water at 10 ^{o}C, a large number of students would predict a final water temperature of 20 ^{o}C. These students would be certainly using Superposition Reasoning, not valid for this case.

Many students seems to think that if 1battery makes a bulb shine, then 2 batteries (even if connected in parallel) would make the bulb shine with double intensity. Such conclusion shows the use of Superposition Reasoning, quite common among students of any level.

What we have called Superposition Reasoning seems to be just an erroneous generalization of the multiple causal attribution (See Bunge, 1979). If a cause C (the battery) produces an effect E (bulb shinning), then, the simultaneous occurrence of two C causes -C1 and C2- (two batteries) will produce an increased E effect (bulb shinning). Similarly, if the same C cause (the battery) has to produce two effects -E1 and E2- (two bulbs shinning) the effect will appear weakened.

Both, 'Sequential' and ,what we have called 'Superposition Reasoning',could be recurrent schemes of reasoning among students which lead them to make systematic mistakes in their predictions. But, what would it be the advantage for the researchers of using such 'mediators', other than an ` interesting academic game?´ (Viennot, 1985). We can argue that the utilization of mediators will result in advantages related to three main aspects, as: a) they will help to make a more effective description of the results, by assembling a wide range of answers under a global label; b) they will provide interesting elements for the study of the complex world of human reasoning; and c) they could be useful in teaching to make students aware of their own way of reasoning.

3. METHODOLOGY: SAMPLE AND INSTRUMENT.

The experimental design was a cross-sectional study of a sample of university students stratified according to the educational level. A specific questionnaire including a set of interconnected questions was designed to allow students to make predictions and interpretations on different situations related to electric circuits.

3.1 SAMPLE.

The sample consisted of 273 students of the Simón Bolívar University, Caracas, Venezuela. Table 1 shows the stratified sample characteristics: ages, and educational level.

Layer	Educational Level	No.	Age (years)
LE1	First year (Physics 1)	47	17.6
LE2	Second year (Physics 3)	63	19.4
LE3	Second year (Electric Networks 1)	110	19.7
LE4	Third year (Electric Networks 4)	53	20.8

Table I. Sample characteristics.

We have selected 4 groups of students -LE1, LE2, LE3, and LE4 - as described in Table 1. We decided to compare the responses of groups LE1 and LE2 - made up by students that had not covered electric circuits' topic at the moment we made the study- with the responses of groups LE3 and LE4 - consisting of students that having already covered electric circuits' topic were studying 'electric networks' at the moment we made the study.

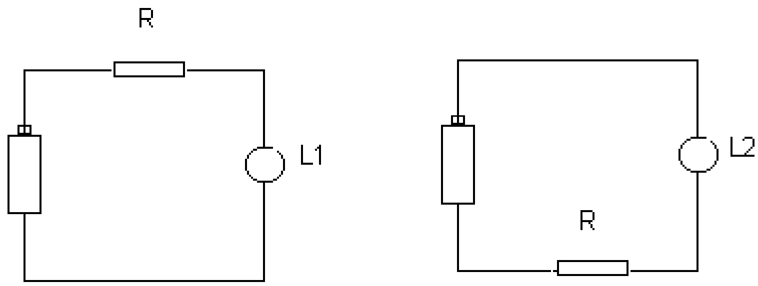
3.2 INSTRUMENT.

The questionnaire used was a multiple--choice-test, normally related to predictions about shinning of bulbs connected to batteries and resistances. Every answer included an open justification section where students explained the reasons of his selection.

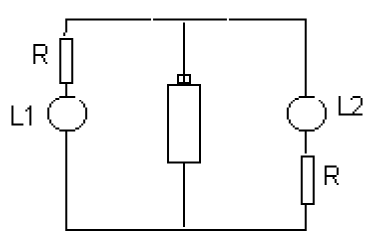
The test included 15 questions, mainly adaptations of the items used by Shipstsone *et al,* (1988), and Dupin & Johsua (1987). Among them, three were closely related to Sequential Reasoning (Mediator M1), and two with Superposition Reasoning (Mediator M2); the remainder were aimed to present a more complete framework of students' interpretations on electric circuits, such as: intensity-voltage relationship, ramified circuits, etc.

Figures 2 and 3 show the situations related to Sequential Reasoning and Superposition Reasoning respectively.

Q11. In the circuit represented in the figure, batteries, bulbs, and resistances are identical.
Which of the following statements do you think is correct?
A) L1 shines equal to L2; B) L2 shines more than L1; C) L1 shines more than



Q12. In the circuit represented in the figure, batteries, bulbs, and resistances are identical.
Which of the following statements do you think is correct?
A) L2 shines less than L1; B) L2 shines equal to L1; C) L2 shines more than L1.



Q13. In the circuit represented in the figure, batteries, bulbs, and resistances are identical. Initially, resistances R1 and R2 are equal. If the value of the resistance R2 is duplicated we can say that: A) The shine of L1 and L2 remain equal. B) The shine of L2 decreases and the shine of L1 remains equal; C) The shine of L1 decreases and the shine of L2 remains equal; D) The shine of L1 and L2 decreases equally.

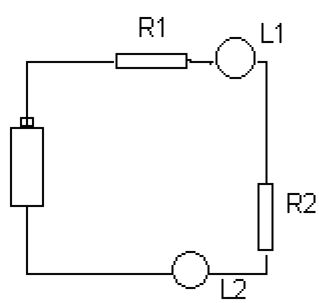
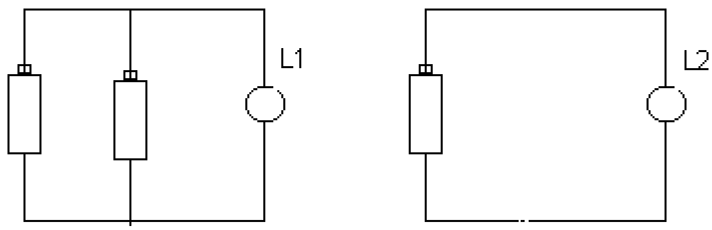


Figure 2

Q21. In the following circuits, batteries and bulbs are identical. With respect to the bulbs´ shine we can say that: A) L1 shines more than L2; B) L2 shines equal to L1; C) L2 shines less than L1.



Q22. In the following circuits, batteries and bulbs are identical. With respect to the bulb´s shine we can say that: A) All shine equally; B) Only L1 and L2 shines equally; C) Only L1 and L3 shine equally; D) L2 and L3 shine less than L1.

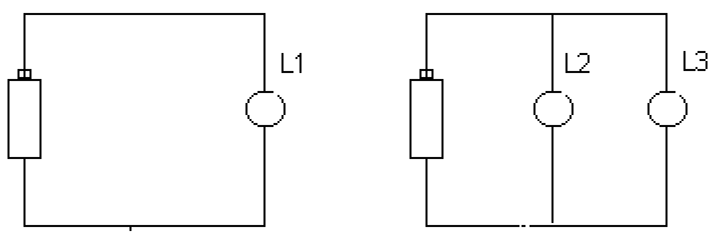


Figure 3

4. RESULTS.

The percentages of correct answers (CA) and Alternative Answers (AA) to the questions that could be interpreted using a Sequential Reasoning mediator are shown in table II.

CA	Q_{11}	Q12	Q13	AA	Q11	Q12	Q13
LE1	27.6	29.8	19.1	LE1	72.4	68.1	65.9
LE2	52.4	41.3	15.9	LE2	41.3	46.0	55.6
LE3	54.5	59.1	37.3	LE3	43.6	27.3	43.6
LE4	100.0	100.0	92.4	LE4	0.0	0.0	0.0

Table II: Percentages of correct answer (CA) and alternative answer (AA) to items Q11,Q12, and Q13, given in every level of the sample.

Table II shows that the rate of Correct Answers were low among students of the first university level (LE1). The proportion of Correct Answers to items Q11 and Q12 increases remarkably between levels LE1 and LE2, even if in those levels students do not have courses that include electric circuit topics. On the contrary, the proportion of Correct Answers to item Q13 decreases between LE1 and LE2. Such decrease in higher educational levels is an example of "Cognitive Regression", already studied by Closset (1989) for the Sequential Reasoning. Surprisingly, while this regression phenomenon takes place for the answers to item Q13, an important "cognitive progress" occurs in the apparently similar items Q11 and Q12.

In level LE3, students have taking courses that include current and circuits topics at a level of introductory physics. Nevertheless, the results of Correct Answers to items Q11 and Q12 showed almost no significant variation; while answers to item Q13 do evolve significantly ($p < 0.01$). Between levels LE3 and LE4, the proportions of Correct Answers to the three items mentioned before showed a considerable evolution ($p < 0.001$).

Table III shows the correlation between the Correct Answers to Q11, Q12, and Q13, and Alternative Answers to the same items.

CA	Q11Q12	Q11Q13	Q12Q13
LE1	0.7411	0.3034	0.2745
LE2	0.5410	0.1704	0.3791
LE3	0.8000	0.5906	0.5271
LE4	1.0000	0.4300	0.4300

AA	Q11Q12	Q11Q13	Q12Q13
LE1	0.8011	0.5596	0.3751
LE2	0.7783	0.4003	0.5561
LE3	0.8003	0.6481	0.5696
LE4	1.0000	0.5664	0.5664

Table III. Correlation coefficient between correct answers (CA) to items Q11, Q12, and Q13 and correlation coefficient between alternative answers (AA) to the same items.

The results included in Table III indicate that consistency of students' Alternative Interpretations, apparently based on the 'Sequential Reasoning' mediator, is slightly higher than consistency of Correct Answers learned in formal education. These results are similar to those reported by Clough & Driver (1986); in their study on the usage of the same intuitive ideas across different contexts they have stated that "alternative framework appears to be used more consistently than the accepted one" (Clough & Driver, 1986, p. 1875). The situations presented in items Q21 and Q22 were referred to the concept of potential difference between two points, and they could be interpreted in an alternative way using a kind of Superposition Mediator. The results (percentages) of Correct Answers and Alternative Answers to these items are given in Table IV.

CA	Q21	Q22
LE1	46.8	38.3
LE2	52.4	42.9
LE3	60.9	37.3

AA	Q21	Q22
LE1	46.8	55.5
LE2	46.0	52.4
LE3	32.7	55.4

LE4	90.6	39.6		LE4	7.5	54.7

Table IV. Percentage of correct answers (CA)
and alternative answers to items Q21 and Q22.

Table IV shows an equal proportion of Correct Answers and Alterantive answers to itemQ21 for the first university level; then the proportion of Correct Answers experiences a progressive increase, little important between first levels and highly significant between levels LE3 and LE4 ($p < 0.001$).

The percentage evolution of Correct Answers to item Q22 (battery with one bulb versus battery with two bulbs in parallel) as a function of educational level is graphically represented in figure 4.

As we can see in the figure, the correct answers percentages to item QE22 are essentially constant and do not improve with the increase of educational level. Why does the proportion of Correct Answer to item Q22 do not increase, while that of item Q21 increase? Perhaps the interpretation of the results should be oriented towards a valuation of declarative knowledge, as for instance: "two equal batteries in parallel do not increase voltage", as such knowledge superposes tacit knowledge resulting from a certain way of reasoning. Therefore, the student will give answers to some questions based on declarative knowledge (Q21), and answer some others based on a way of reasoning or tacit knowledge (Q22); this would make interpretations of similar situations less consistent.

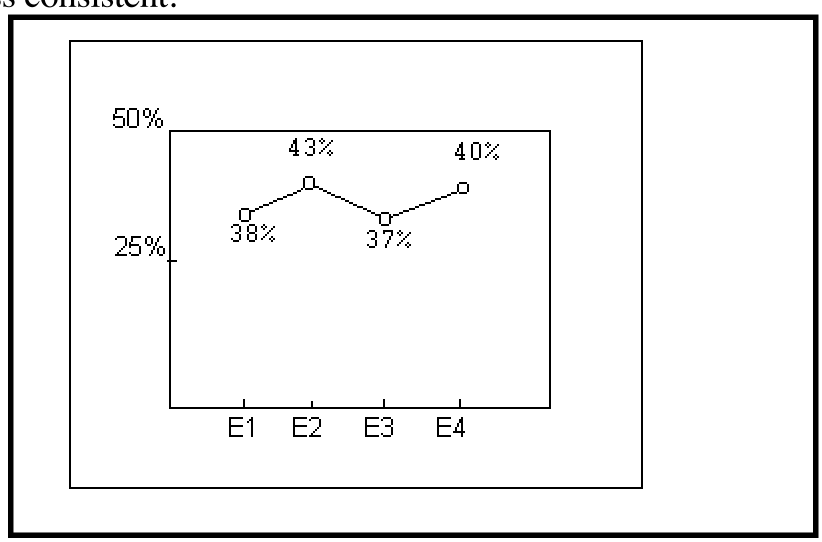


Figure 4

The correlation between answers to items Q21 and Q22, as expected according to answers' uneven evolution, was quite negligible, as shown in table V.

CA	Q21Q22		AA	Q21Q22
LE 1	-0.2127		LE 1	-0.1004
LE 2	0.1819		LE 2	0.2492
LE 3	0.2708		LE 3	0.2087
LE 4	0.1301		LE 4	0.1162

Table V. Correlation coefficient of correct answers (CA)
to items Q21 and Q22, and alternative answers (AA) to3

the same items.

4.1. REFLECTIONS ON THE RESULTS.

This work was intended to explore the utility of two presumed 'mediators' of students' reasoning in electric circuits. The electric circuit sequentiality can be considered (Closset, 1989) as a step in the linear causality adaptation process that starts with the unipolar circuit idea, develops through the clashing currents' model, to culminate in the sequential model. The cases we have assembled under the 'superposition category can be interpreted as multiple causality: plurality of causes and diversity of effects (Bunge, 1979).

Then, If the results can be analyzed through causality (Gestalt of causation, Andersson, 1986, causal constraints, Sebastià, 1989), would it be useful to introduce other mediators? We believe that it would. The term causality is so large that it seems suitable to introduce more specific mediators; "if such a description is to be effective it must propose mediators of a proper size" (Viennot, 1985, p. 157).

KNOWLEDGE OR WAY OF REASONING?

The correlation results mentioned above show that students' interpretations of items Q11, Q12, and Q13 are reasonably consistent, both when the answers are correct and when they could be the result of a kind of sequential reasoning. On the contrary, the students'answers to items Q21 and Q22 are very little consistent.Does it mean that a sequential mediator is appropriate to interpret the results, and a superposition mediator is not? Probably, but we believe that the interpretation of consistencies is related to a phenomenon latent in all the studies carried out in the domain of alternative conceptions: the interaction between declarative knowledge K, resulting from information, and tacit knowledge K', resulting from a way of reasoning. Distinction between K and K' may appear confused in some cases but very clear in others. The fact that "electrons move through the circuit from the negative to the positive pole of the battery" is a concept acquired by verbal or written transmission; but the idea that "two bulbs connected in parallel shine less than only one" could be an inference based on certain epistemological assumptions, of causal nature for this particular case.

We interpret the events using our cognitive tools, but such tools include declarative knowledge K, as well as tacit knowledge K', perhaps resulting from certain constraints in the person's reasoning. The justifications of the answers to items Q21 and Q22 reinforce the aforementioned conclusion. The justification to Correct Answer of item Q21 given by students was frequently: "because they are in parallel", or "because two batteries in parallel do not increase voltage". The answer to item Q22 was, however, often justified by the phrase: "the current is divided", or "the voltage splits", which shows a way of reasoning more than acquired knowledge.

CONCEPTUAL STABILITY OR CONCEPTUAL CHANGE?

The analysis of the results shows an important increase of Correct Answer percentage in the majority of the items (Q11, Q12, Q13 and Q21), specially between level LE3 and LE4 ($p < 0.0001$). On the contrary, we observe no significant change in the proportion of answers to item Q22. What does this exception mean? Does teaching produce a conceptual change or not?

Data provided here seems to further prove that there is not a conceptual change leading to put aside a series of ideas in order to replace them for others (White & Gunstone, 1989), but an evolution strongly related to the situation. We agree with Di Sessa (1988), that students interpret reality on the bases of "knowledge-in-pieces schemes", that is to say, using a large number of knowledge fragments not interconnected rather than theories. The variants of a given situation are frequently interpreted according to their analogy with the preceding one; but when students do not identify the new situation as being a variant of preceding ones, they come back again to those interpretative schemes that they had apparently abandoned. The basis of all predictions, and therefore of understanding, seems to be "a set of base-level or paradigm situations which the child really knows about" (Millar, 1989, p. 594). From this perspective, the preceding knowledge is not destroyed; instead, the different knowledge organizations are linked to their respective "domain of practice" (Tiberghien, 1989), therefore such knowledge may be applied any time as answers to specific situations.

REFERENCES

ANDERSSON, B.,1986. The experimental gestalt of causacion: A common core to pupil´s preconceptions in Science: *European Journal of Science Education*. Vol. 8, pp. 155-171.

BUNGE, M., 1979.*Causality and Modern Science*. Dover Publications. New York. 3rd Edition.

CLOSSET, J.L.,1983. Sequential reasoning in electricity. In *Resarch on Physics Education*. Proceedings of the First International Workshop. La Londe Les Maures. France.

CLOSSET,J.L., 1989. Les obstacles à L´aprentissage de l´electrocinetique . *Bulletin de L´Union des Physiciens*. No. 716, pp.931-949.

Di SESSA, A.A., 1985. *Knowledge in pieces*. University of California. Berkeley.

DUPIN, J.J. an JOSHUA, S.,1987. Conceptions of french pupils concerning electric circuits: structure and evolution. Journal of *Research in Science Teaching*. Vol. 24, No.9, pp.791- 806.

MILLAR, R.,1989. Constructive criticism.*International Journal of Science Education*. Vol.11, pp.587-596.

SEBASTIA, J. M., 1989. Cognitive constraints and spontaneous interpretations in Physics. *International Journal of Science Education*. Vol. 11, No. 4, pp. 363-369.

SHIPSTONE, D. *et al*.,Study of students understanding of electricity in five european countries. *International Journal of Science Education*.Vol. 10, No. 3,pp. 303-316.

STRAUSS, S. and STAVY, R., 1983. Eduacational developmental psychology and curriculum development: the case of heat and

temperature. In *Proceedings of the International Seminar on Misconceptions in Science and Mathematics*. Cornell University Press.
Novak, J. (editor). Ithaca. New York.

TIBERGHIEN, A.,1989. Phénomènes et situations matérielles: quelles interpretations pour l´elève et pour le physicien?. *Construction des Savoirs:Obstacles & Conflits*. Les Editions Agence D´Arc. Ottawa. Canada.

VIENNOT, L., 1985. Analysing students´ reasoning in science : a pragmatic view of theoretical problems. *European Journal of Science Education*. Vol. 7, pp. 151-162.

WHITE, R. T. and GUNSTONE, R. F., 1989. Metalearning and conceptual change.*International Journal of Science Education*.Vol 11, pp. 577-586.