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Conceptions of pupils of the primary on the topic of an electric circuit in three countries (Canada, France and Morocco)

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Abstract
Qualitative research conducted with 237 pupils from Canada, France, and Morocco, between 10 and 12 years of age, on the setting and functioning of simple electric circuits, demonstrates that similar explanatory systems of the students. For this, we had given them a paper and pencil questionnaire of a sixty minutes duration. The first question was related to power a light bulb using wires and battery. The second issue was intended to determine whether pupils are conscious of the danger associated with a polarity battery. The third is related to the flow of electric current between the + and - terminals of a battery in an electric circuit. The last question requires an understanding of the law of conservation of the charge in a circuit constituted by a battery and a bulb. This research provides an answer to the question of ethnocentricity and universality of students' conceptions from different cultures and linguistic communities. In this research, the thesis of the universality was establish from the students' responses to a questionnaire.

Keywords: conception, electrical circuit, pupils, universality.

Introduction

There is consensus today among researchers in the didactics of sciences concerning the important role of the ideas that pupils have about phenomena that underlie scientific concepts taught in school programs. These ideas or conceptions, developed in the absence of a formal teaching, are an integral part of the cognitive development of the pupils. Hewson and Hewson (1984), Driver et al. (1994), Read (2004), Vosniadou et al. (2008) assert in this regard that teaching that doesn't start from the pupil's point of view cannot arouse in him an active involvement, indispensable for the complex process of constructing scientific thought. Indeed, teaching that starts from the pupil's perspective and the meaning that things have for him stimulates his reasoning and his imagination. Also, educational support helps the pupil to develop more fruitful ideas in the sense of Posner et al. (1982), not because he has been told that these are the ideas that he must learn but because he becomes convinced and motivated by the utility of these ideas and their plausibility. Moreover, to be able to speak of a phenomenon or an object is closely bound to the understanding of this phenomenon or this object. The mental models are, consequently, internal conceptions of objects, state of things, sequences, events or processes about how the world is and on psychological and social actions. They allow individuals to understand phenomena and events, to make predictions and inferences about them as well as to make decisions and control their execution (Borges and Gilbert, 1999).

It is the very essence of the constructivist vision that seems to predominate in the last few years and by which von Glasersfeld (1994) refers to the understanding of the pupil's conceptual world as a prerequisite to the "success" of teaching. These spontaneous conceptions that children have are anchored in the language, the culture and everyday life whose meanings are negotiated socially

(Solomon, 1993). However, we realize that these conceptions are in discontinuity with the concepts of the scientific community. With words sometimes similar and sometimes different, science interprets reality according to parameters of another order that the one used in ordinary life, creating epistemological obstacles for the learning of sciences (Astolfi, 1995; Bachelard, 1980; Giordan and de Vecchi, 1987). Therefore, there is a real challenge for the researchers in the didactics of sciences to offer a pedagogy that, with the help of structuring activities, allows to confront, to sustain and to guide the pupils in the learning of scientific explanations.

On this topic, there is a body of research in industrialized and non-industrialized countries on the spontaneous conceptions of children about scientific phenomena. In their research, some scholars infer that these spontaneous conceptions are similar through different cultures (Driver, Squires, Rushworth and Wood-Robinson, 1994; Métioui and Baulu-Mac Willie, 2013).

There are, however, other scholars who, from their works, infer on the contrary that these conceptions are not similar among different cultures (Lowe, 1997; Maskill, Cachapuz and Koulaidis, 1997; Lynch, 1996). In spite of studies done in several countries, the number of systematic research through different cultures is rather limited. In any case, the development of this question is important when children of different languages and cultures meet in a same school environment. In the perspective of internationalization of knowledge (Delors, 1998), this problem is meaningful since a better understanding of this question would not only ensure better targeted curriculums of sciences but, also teaching whose educational approaches would give pupils better odds of success.

Ethnocentricity or universality of pupils` conceptions on electric circuits

Among the research on the important theme of electricity, the functioning of a simple electric circuit has not been studied very much in this perspective, particularly among the pupils at the primary level. What has been achieved only represents isolated and fragmentary studies (Osborne, 1981; 1983; Russel, 1980; Sarrazin and Genzling, 1988; Shipstone, 1984; Solomon, Black Oldham and Stuart, 1985; Tiberghien and Delacôte, 1976). Systematic research that could indicate if there are parallels or ethnocentricity of spontaneous conceptions about this phenomenon in children's minds at the primary level in different cultures would give a more complete picture of these conceptions.

Of an exploratory nature, the present qualitative research has attempted to identify the spontaneous conceptions of pupils from three countries about the necessity of a closed electric circuit for the flow of energy in the wires and its conservation. The results are presented and are analyzed in light of the universality or ethnocentricity character of the conceptions.

Population

In this study, the reconstitution of the conceptions has been achieved from a sampling of 237 pupils of grade 5 (Canada) and its CM2 (France and Morocco) equivalent. The ages of the pupils vary from 9 to 13 years. The number of subjects in each of the countries is as follows: Canada (N = 115), Morocco (N= 92) and France (N = 30). In Canada, there are two distinct groups. The first is from an Acadian region of Nova Scotia (N = 69). Registered in a French-speaking public school, the schoolchildren speak French and English. The French spoken by these pupils is a linguistic variation of standard French because of its history and its minority situation in the province. The second group was chosen from the Quebec public school system in Montreal (N = 46) where the maternal language and the language used in the school is French. In Morocco (N = 92), the subjects were chosen from two private French schools in the region of Casablanca. The languages spoken by these children are Moroccan, Berber and French. However, French and Arabic are learned as part of the curriculum. The pupils of Morocco distinguish themselves from the other groups by the fact that they are the only ones to have some knowledge in certain aspects of the functioning of electric circuits. In France (N = 30), the

children were chosen from two public schools in Poitiers. Their language is French. In the complete sampling, English is also a language learned as part of the curriculum.

Questionnaire

The data collecting uses a paper-pencil questionnaire, as presented in the annex. The questions were constructed on the basis of studies done by various researchers: Jabot & Henry (2007), Mackay & Hobden (2012); Osborne (1981; 1983), Russel (1980), Sarrazin and Genzling (1988), Shipstone (1988), Solomon et al. (1985), Tiberghien and Delacôte (1976). The objective of the two first questions was to verify the pupils' notions of a closed circuit. It is important to note that, generally, children are confronted with this type of circuit in the replacement of worn-out batteries, pocket-size lamps, walkmans, or all other objects functioning with batteries. Unfortunately, the spoken language does not help these children to conceptualize the nature of a closed circuit since they are often asked to turn on a light in a given piece by opening the switch. Thus, to the first question, the pupils must make a choice from different arrangements of batteries, bulb and wires as well as explain why the bulb would light up with the choices made. In the second question, the pupil must decide if only one terminal or the two terminals of a 1000-V battery would be deadly to touch and explain his answer. This situation refers to the notion of a closed circuit and, therefore, neither the positive pole nor the negative pole would be deadly to touch. The last two questions concern the displacement of the loads and their conservation. Thus, in the third question, the pupil must choose one of the descriptions of the flow of an electric current and justify his choice. Finally, in the fourth question, the pupil must choose the best explanation for the conservation of the current when the bulb is lit and, there again, to explain his choice. Everything takes place in a classroom under the teacher's supervision. The teacher can help the pupil understand one question or another but, doesn't offer any help for the answer.

Results of the experiment

In order to personalize the information, while preserving anonymity, the participating pupils have been identified by the Enei letters (ième in the region of Clare), Epi letters (ième in Poitiers), Eci letters (ième in Casablanca) and Em letters (ième in Montreal). 25% (Casablanca), 3% (Poitiers), 0% (Montreal) and 1% (region of Clare) of the pupils' state, in the case of the first question, that the (D), (F), (G), (H) and (I) arrangements make the bulb light up while the other arrangements don't make it light up. It is a good answer of which here are some examples:

"I think that (H), (F), (G), (I), (D) are going to light up because the terminals (+) and (-) are plugged to the bulb". (Enei37)
"The bulb touches the positive terminal and is joined to the negative terminal or the reverse". (Epi18)
"(D) because the bulb touches a terminal and the electric wire touches the other terminal. (F) because the battery is touched by 2 electric wires and the bulb shines. (G) because the two batteries are touched at the two terminals. (H) because the battery has a wire that touches the contact. (I) because the battery has two wires: one that touches the base and the other that touches the contact". (Eci4)

However, 16% (Casablanca), 13% (Poitiers), 37% (Montreal) and 28% (region of Clare) of the pupils do not indicate all arrangements that will turn on the bulb; however, those indicated are right.

Finally, 52% (Casablanca), 67% (Poitiers), 48% (Montreal) and 54% (region of Clare) of the pupils chose the E diagram and others, except the diagrams (A), (B), (C) and (J). The closed circuit notion is not understood by these pupils since for the majority of them, it is sufficient that the poles (+) and (-) of a same battery or of two batteries be connected, without paying attention to the terminals of the bulb, the contact and the base. With regard to the second question, 12% (Casablanca), 7% (Poitiers), 13% (Montreal) and 6% (region of Clare) of the pupils' state rightly that it is dangerous to touch the

two terminals of the battery simultaneously in order to close the circuit. However, 42% (Casablanca), 50% (Poitiers), 39% (Montreal) and 59% (region of Clare) of the pupils give an erroneous answer in stating for example that it would be deadly to touch the terminal (+). They offer the following reasons:

"If I touch (+), that will kill me because (+) is stronger than (-)". (Enei5)
"The + terminal would be deadly because there would be a lot of current". (Epi3)
"It will be deadly to touch the (+), it is (+) because (-) is not really deadly". (Emi2)
"I think that it would be deadly to touch the (+) terminal because 1000 volts is a lot and the (+) terminal is more dangerous than the (-) terminal". (Eci5)

On the questions related to the flow and conservation of the current, the given answers to the third question reveal that an important number of pupils (Casablanca 33%, region of Clare 35%, Montreal 41%, and Poitiers 57%) refer to the model of antagonistic currents. It is about choice (b) considering that two currents leave the two terminals of the battery simultaneously and meet in the bulb, which allows the bulb to light up. This model, plausible in its appearance, is incorrect. Here are some justifications offered by the pupils:

"It lights up because the electricity crosses itself in the filament". (Eci7)
"Because when the electricity will move from the (+) terminal and the other from the - terminal and meet in the bulb, it lights up". (Eci25)
"I think that it is because the two tips of the battery meet in the bulb". (Enei43)
"I believe that the (+) terminal has more energy than the - terminal and, for the bulb to light up, it is necessary that they leave from one tip and arrive at the other". (Emi25)
"Because when the two currents cross, it makes a spark which lights up the filament". (Epi8)

Another non negligible proportion of the pupils (Casablanca 50%, region of Clare 52%, Montreal 45%, and Poitiers 27%) refer implicitly to the scientific model in order to interpret the lighting up of the bulb. It is about choice (d) considering that the charges (thought of as positive) circulate from the positive terminal of the battery towards the negative terminal while passing through the bulb. This model is correct as indicated in the following answers by the pupils:

"Because the circuit of the + terminal is at the contact, then goes up, crosses the filament and returns to the (–) terminal, and continues to circulate". (Eci5)
"A bulb needs for the electricity of the (+) terminal to pass in a spiral thread in the bulb and return in the battery and circulate. If it does not circulate, it will not function". (Enei61)
"Because it circulates the whole time and it doesn't stop". (Emi11)
"Because the battery will light up the bulb and will come back by the terminal to the battery and it will continue to circulate because we know if it makes a discharge". (Epi20)

The analysis of the data in the fourth question shows that a large number of pupils (Casablanca 52%, region of Clare 65%, Montreal 28%, Poitiers 46%) accept the principle of the conservation of the charges, namely that in a closed circuit the current is everywhere the same as is shown in the following quotes:

"Because the electricity that is in the battery gives some to each terminal, as much to one as to the other". (Eci25)
"Because B and A form a circuit". (Enei19)
"Because the current must be of the same strength so that the bulb can light up". (Emi14)
"Because the current goes through a wire to pass on the electricity to the other wire that turns on the light". (Epi22)

Finally, 36% (Casablanca), 54% (Poitiers), 59% (Montreal) and 25% (region of Clare) of the pupils' state that the currents in the wires A and B are different as illustrated in the following comments. Note that they do not understand the principle of conservation.

"Because the A wire comes of the (+) terminal and the B wire comes of the (-) terminal so the wire A has more electricity to give to the bulb". (Eci3)
"Because (-) means (-), less power. (+) means that there is more power, (+) for more". (Enei48)
"In the pale part of the battery, there is less energy because it is smaller than the dark part. The B part is joined underneath the bulb; it is there where there is more energy". (Emi43)
"Because on the battery, it is written (-) and (+) therefore I think that A has more power than B which has less". (Epi19)

The results of this exploratory study attest to a striking parallel between the spontaneous conceptions of the children on three continents and in distinct countries. The interpretation that one can make may be attributed to the subject at hand, to the working of a simple electric circuit and to the cultural environment in which these conceptions have been collected. On the one hand, the technical object that the simple electric circuit represents is an equipment with symbols that are similar (a battery with the sign (+) and the sign (-) on its terminals, a bulb with a filament inside joined to the terminal of the bulb, the contact and the base and the electrical connecting wires), no matter what country in which one finds oneself. On the other hand, the majority of the pupils in the study live in an urban or rural environment of western countries whose technological level is such that they recognize these particular aspects present in the culture.

Conclusion

In the context of the internationalization of knowledge, the results of this research show the relevance of developing new research of comparative nature on the spontaneous conceptions of the children about the functioning of a simple electric circuit in many countries and, especially, in regions where modern technology is not predominant. Such research would allow a better understanding of what can be learned from the relationship between the unscientific knowledge of the spontaneous conceptions and the scientific knowledge of the concepts to learn (Black and Lucas, 1993). They would especially allow to pinpoint the central basis of the spontaneous conceptions: if the markers are the static state of the system or the particular components that could refer to the movement; if the reasoning is sequential or causal; if the conceptions are undifferentiated (current, electricity, power); if they are dependent on the context; or, if there is a predominance of certain conceptions. The fact that the pupils of this study have difficulty to conceptualize the technical ideas of an electric circuit, made of a battery and a bulb and with the underlying principles of its functioning, indicates to us that there are particular educational interventions to be developed if one wishes that a non scientific thought dominated by spontaneous perceptions can transform itself to become a scientific thought. Indeed, the pupil should construct some models which, according to Driver et al. (1985), suppose the use of some entities, objects or systems, and the use of some parameters to explain the interaction processes between the different components of these entities. For example, in the case of the electric circuits, the task is to better understand the complex notions of current and tension. This construction requires an important intellectual effort by the pupil and also takes time to become stable. Yet, these are the cognitive tools to search in the context of the complexity and the internationalization of scientific knowledge.

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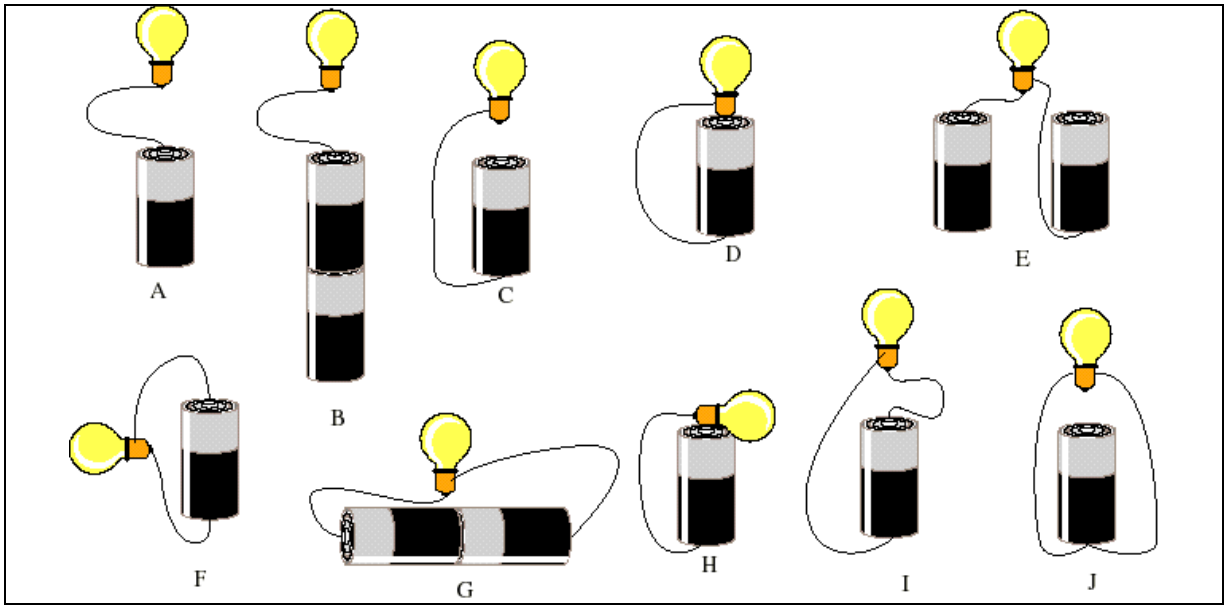
Appendix
Questionnaire paper-pencil

Question 1: Among the arrangements of batteries, bulbs and small wires presented below, surround the one or those that will make the bulb light.



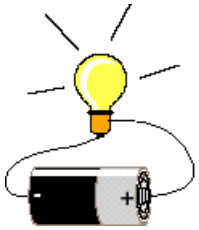
Explain why the bulb will light up with the choice or the choices that you have made.

Question 2: If one had a battery of 1000 Volts, what terminal (+) or (-) would it be deadly to touch or would no terminal be deadly to touch? Explain your answer.

Question 3: Surround the letter corresponding to the sentence that appears most correct to you to explain why a bulb plugged to the terminal (+) and (-) of a battery ignites:

a. A current circulates of the terminal (+) of the battery toward the bulb and stop there.
b. Two currents, one of the terminal (+) and the other of the terminal (-) of the battery meet in the bulb.
c. A current move from the terminal (+) on the battery toward the bulb to comes back to the battery by the terminal (-) and stops there.
d. A current move from the terminal (+) of the battery toward the bulb and comes back to the battery by the terminal (-) and continuous to circulate.
e. No to all these answers.

Explain why the bulb will light up with the choice you have made.



Question 4: In the following diagram, the two wires that join the battery to the bulb have been identified by the letters A and B and the bulb is lit.
Surround the letter that corresponds best to explain the current in the circuit:

a. The current in the wire B is weaker than the current in the wire A. b. The current in the wire B is bigger than the current in the wire A. c. The current in the wire B is the same that the one in the wire A. d. None of these answers. Explain why the bulb will light up with the choice that you have made.