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CONCEPTIONS ABOUT ELECTRICAL CIRCUITS OF ENGLISH AND FRENCH PUPILS FROM NOVA SCOTIA IN CANADA

English And French Conceptions On Electric Circuits

ABDELJALIL MÉTIOUI, LOUIS TRUDEL

University du Québec, Canada
Université d'Ottawa, Canada

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ABSTRACT

This research study was designed to identify the conceptual understandings of 89 students from the region of Clare in French-language public schools and 105 students from the Argyle region in French immersion public schools in Canada on the operation of simple electrical circuits. To this end, they completed a pencil-and-paper questionnaire of sixty minutes in duration. The analyses of the data show clearly the preponderance of erroneous understandings by students related to the concepts of current and voltage among other related concepts identified in the international review of the literature. Thus, despite the cultural and language differences, their conceptual understandings related to the simple electrical circuit are similar. A conclusion and didactical impact are included.

GLOBAL KNOWLEDGE ACADEMICS

1. Introduction

Extensive research conducted with elementary and secondary pupils (7 to 14 years old) about their conceptions related to different natural and constructed phenomena with which they interact daily reveals that they are similar despite socioeconomic and cultural differences (Métioui & Baulu MacWillie, 2013, 2015; Tao et al., 2012; Allen, 2010; Jabot & Henry, 2007; McDermott, 2004). On this subject, McDermott (2004) highlighted that "[...] research findings on students' understanding of physics indicate that some misconceptions about the physical world are familiar to students of different nationalities, from different socio-cultural backgrounds and different levels of education and varied ages". (Page 1) Similarly, Tao et al. (2012) demonstrate that Chinese and Australian children from high and low socioeconomic status have the same spontaneous conceptions: "The findings revealed that participating six children from schools with high socioeconomic status from China and Australia demonstrated similar profiles in their understanding of science." It is important to note that these profiles are not the same in the case of secondary pupils and depends on many factors. For example, the Canadian results of the OECD PISA study (2015) demonstrate that French-speaking students (15 years old) in a minority secondary school system perform less well than English-speaking students in a majority school system in sciences. In the case of elementary school students, we found no indication of their science performance. In the present exploratory qualitative research, we will first summarise a review of this work relative to the phenomena requiring the understanding of scientific concepts as electrical current, time, speed, acceleration, force, energy, heat, and temperature with elementary pupils aged 7 to 12. Then, we will present the results of our research on a comparative study of French and English-speaking students from Nova Scotia in Canada to verify if the Anglophone performs more than French as in the secondary school revealed in the OECD PISA study. In this, we have identified the conceptions of Anglophone and Francophone students in Nova Scotia on the principles of simple electrical circuits inscribed in the Elementary School Science of the Ministry of Education.

2. Literature reviews about pupils' conceptions from different cultures and countries

Studies carried out in many countries with pupils aged between 8 and 12 demonstrate that they have relatively the same conceptions to explain different physical, chemical and biological phenomena with which they interact daily. Below we summarize the most widespread pupils' conceptions from different countries about notions related to the physical world. These studies attest to the universality of their understandings.

2.1. Conceptions about velocity

Works done with pupils aged 7 to 12 and attending primary schools in Italy (Invernizzi et al., 1989), in France (Canal, 1986), in Canada (Métioui & Baulu MacWillie, 2013) and elsewhere indicate that their spontaneous conceptions concerning speed and time, despite the cultural and economic differences of these countries. The majority of pupils associate time with either: 1. The units of measurement (e.g., hours, minutes, seconds); 2. The duration of the day, month, year or century; 3. The climate (e.g., autumn, winter, spring, summer); 4. The games and accidents (e.g., car race); 5. To life (e.g., joy, sadness, luck) and 6. To speed of movement or speed. As for speed, they associate it with movement without acceleration or with the characteristics of moving objects (e.g., the engine and the mass of a car).

2.2. Conceptions about force, motion, acceleration and gravitation concepts

Much research has focused on the conceptions of students between 10 and 14 years old on the concepts of force, motion, and gravitation (Watts, 1983; Métioui & Trudel, 2017). The misconceptions commonly accepted by students from different cultures and countries are: the motion implies force; when two objects have the same position, they should have the same velocity; the velocity of an object is proportional to the force applied; if an object moves in the circular path, a circular force tends to move this object in its path; acceleration is an increase in speed; speed of a falling body is proportional to its weight; weight is the quantity of matter (mass), energy is a force and there is no gravity on the moon.

2.3. Conceptions about electrical circuits

In the case of electrical circuits, regardless of the country, the pupils aged between 8 and 12 have the same erroneous conceptions. Indeed, studies conducted in the USA (Fredette & Lochhead, 1980), Canada (Métioui et al., 2016; Métioui & Baulu MacWillie, 2015); France (Tiberghien & Delacote, 1976; Thiberghein, 1983), New Zealand (Osborne, 1982); Australia (Webb, 1992) and elsewhere with pupils in elementary schools established that their majority refer to one of the erroneous following models to explain the flow of the current in a simple circuit consisting of a battery, light bulb, and electrical connection wires: (1) Unipolar model; (2) Clashing currents model and (3) Attenuation model. Relative to the transformation of energy in a simple circuit composed with bulb, battery and two wires their conceptions are as; 1. There is no difference between light and electricity since light produced by electricity; 2. There is a difference between heat and electricity since with heat one cannot operate devices such as a television; 3. The light in the bulb comes from electricity contained in the battery, and 4. There is a difference between light and electricity since light cannot produce electricity.

2.4. Conceptions about heat

Students' conceptions of heat and temperature have been the subject of much work around the world (Erickson, 1980, Engel Clough & Driver, 1985; Tiberghien, 1985; Carlton, 2000; Sözbilir, 2003; Chu et al., 2012; Métioui, 2019). Students consider heat as a substance with properties attributed to material objects and often see hot and cold as two distinct and opposite phenomena that are not part of the same continuum. Also, for most, the temperature is a property of matter, some objects being hotter or colder than others (for example, metal are more cooling than wood). Finally, relative to the relationship between heat and temperature, for many students, the temperature is a measure of the degree of coldness or warmth of a substance. Note that many well-known scientists constructed some of these erroneous conceptions during the eighteenth century (Fox, 1971; Métioui, 2019).

2.5. Conceptions about light and vision

The notions of light and vision in students have also been the subject of many works (Tiberghien et al., 1980, Selley, 1996, Dédès & Ravanis, 2007; Ravanis et al., 2010; Métioui, 2012). The following conceptions identified in these works are related to the students' daily experience and their first intuition: 1. The size of an object's shadows varies with the intensity of the bulb; 2. Light propagates in a straight line, but only in the horizontal direction; 3. Light is reflecting when meeting an obstacle on its path; and 4. Light changes direction in the same area of propagation.

3. Methodology and population

To identify the conceptions of 89 pupils from the region of Clare in French-language public schools and 105 from the Argyle region in English-language public schools aged between 10 and 12 years, we have given them, a paper and pencil questionnaire of sixty minutes' duration. To complete it, they had to use their conceptions since they have received little training on the topic connected to the concepts related to the study of simple electrical circuits. In table 1, we present information relative to the two groups of students belonging to two different communities in Nova Scotia (Canada). These studies attest to the universality of their understandings.

Table 1.
Population

Region of Clare, Nova scotia	Region of Argyle, Nova scotia
Linguistic	
Spoken languages: French vernacular with significant linguistic variations and English	
Economic	
Diversified economy helped by the Economic Development Council of Nova Scotia (CDENE).	Economy a little more prosperous because of the lobster fishery that brings in a lot of money. Support from the Nova Scotia Economic Development Council (CDENE).
School	
Public elementary and secondary schools.	
Geographical	
The fishing industry is important in the regions of Argyle, Clare, Isle Madame and Cheticamp. The most prosperous in Atlantic Canada is the Argyle region.	

4. Paper-pencil questionnaire: Construction and analysis

The questionnaire we constructed covers some program concepts related to the study of the simple electrical circuit, especially the law relatively the flow of the current. For that, we presented them with three questions. Below we present the objective of each question and its analyses.

5. Objective and analyses of the data of the first question

This question served to know how the students explain to light the bulb we must connect the (+) and (-) terminals of the battery to its poles. The analyses of the answer can be classified into three categories conceptual representations described below.

5.1. Category 1: Unipolar model

Following the analysis of pupils' responses, we identified two subcategories related to the unipolar model.

5.1.1. Subcategory 1.1

The current flows from the pole (+) towards the light bulb. It is causal reasoning according to which a current flow from one of the two battery terminals and goes up to the lamp to illuminate its. It should be noted that very few pupils refer to this erroneous model. Tiberghein (1983) underlined that most of the pupils abandon this model during the training of the electric circuits. Table 2 illustrates some pupils' explanations.

Table 2.
Pupils' answers: Subcategory 1.1

French pupils: 2/89	English pupils: 5/105
"We watch it on the canal 'Discoveries'." (F_{28}) "Because the plus is stronger." (F_6)	"The positive end has the most energy." (E_{82}) "The reason why the light will heat up is because of the + sign." (E_{84})

5.1.2. Subcategory 1.2

The current moves from the pole (+) to the pole (-) and then stop. Contrary to the precedent unipolar model, the current flow from one pole to the other pole of the battery for the light bulb to come on. These students probably think so to take into account the necessity to use the second wire. Table 3 illustrates some pupils' explanations.

Table 3.
Pupils' answers: Subcategory 1.2

French pupils: 6/89	English pupils: 2/105
"I chose (c) because that's what I think it is." (E_{29} /10 years old) "I think (c) is good because they both work together." (E_{82})	"The reason that I picked (c) is that that is the only one that is right for me." (E_{94})

5.2. Category 2: Clashing currents model

Two currents move from (+) and from (-). It should be noted that the anglophone students referred to the word energy without, however, explaining its production in the battery. Table 4 illustrates some pupils' explanations.

Table 4.
Pupils' answers: Category 2

French pupils: 28/89	English pupils: 32/105
"Because the two wires are touching each other and when they meet at the bulb, the light bulb comes on." (F_{72}) "Because it lights up when it is at (+), then it does not light when it is at (-)." (F_{83})	"Because it can give the bulb a source of D.C. energy." (E_{33}) "When you put the positive to negative it creates energy made from the acid in the battery." (E_{38})

5.3. Category 3: Circulatory model

The current moves from the pole (+) to the pole (-) and continues to circulate. Table 5 illustrates some pupils' explanations.

Table 5.
Pupils' answers: Category 3

French pupils: 48/89	English pupils: 57/105
"I think it's going in a circle because if it stops, the light will have no electricity." (E_{67}) "Because it needs to continue because if it does not continue, the light will stop." (E_{70}) "The reason the light bulb comes on is through both wires and the battery." (E_{85})	"Because that is how I thought it would light up before I read it." (E_{85}) "I think it will light up because the energy continues to circulate through the battery and causes the energy to go to the light." (E_{91}) "Because it continues to circulate." (E_{95})

Conclusively, only five French pupils and nine English pupils have advanced incomplete or indecipherable explanations for grouping them into a given conceptual representation.

6. Objective and analyses of the data of the second question

The relative data to this question relates to the principle conservation of the total charge revealed two categories of answers as illustrated below. According to this principle, in each moment the intensity of the current is the same at all points of the wires. The analyses of the answer can be classified into two categories described below.

6.1. Category 1: Attenuated current model

Following the analysis of pupils' responses, we identified two subcategories related to the attenuated current model.

6.1.1. Subcategory 1

The current in the B wire is weaker than the current in the A wire. Table 6 illustrates some pupils' responses.

Table 6.
Pupils' answers: Subcategory 1

French pupils: 19/89	English pupils: 32/105
"The B wire will make the light more than wire A." (E_{28}) "Because (-) it means less, less power, (+) it means there is more power, (+) for (+)." (E_{68}) "The light bulb will turn on because on the battery, the side where there is the B there is a minus (-), and where there is the A, there is a plus (+)." (E_{71}) "The bulb will light up because the A wire is stronger." (E_{72})	"The B wire is weaker because electricity goes up and the A wire happens to be at the top." (E_{25}) "The current in the B wire is weaker because it is on the negative (-) and the current A wire is stronger because it is on the positive (+)." (E_{41}) "The current in the B wire is weaker because B wire is shorted than A wire." (E_{36}) "The current B wire is weaker because it is on the (-) side." (E_{39})

6.1.2 Subcategory 2

The current in the B wire is stronger than the current in the A wire. Table 7 illustrates some pupils' responses.

Table 7.
Pupils' answers: Subcategory 2

French pupils: 6/89	English pupils: 6/105
"I think B is stronger because the B cable is black and bigger." (E_{18}) "I think it's B because I tried it before." (E_{29}) "It's because it's a current that goes on all the time." (E_{42})	"Because B is touching the bottom and that is where the bulb works." (E_{3}) "The bulb lights up with the A wire and the B gives it strength." (E_{87}) "Because the B wire has to be stronger than the A wire." (E_{89})

6.2. Category 2: Scientific model

The current in the B wire is the same as the one in the A wire according to the principle of the conservation of the electric current Table 8 illustrates some pupils' responses.

Finally, only 6% (5/89) of French pupils and 10% (11/105) of English pupils have advanced incomplete or indecipherable explanations for grouping them into a given conceptual representation.

Table 8.
Pupils' answers: Category 2

French pupils: 59/89	English pupils: 56/105
"The electricity flows in the metal faster and it makes a current." (F_{2}) "From the photo, the wires are equal." (F_{8}) "If they were not the same, it would not work." (F_{22}) "The c because that's what I think." (F_{33}) "Because it's electric current and the light will come on because it's the same battery." (F_{52}) "Because if both are the same, they would light up easier together because there is the same energy." (F_{75})	"With the choice, I have made the bulb will light up because the B wire is the same as the A wire." (E_{27}) "It will light up because the bulb has a source of DC energy." (E_{33}) "It takes twice ends of a battery and a wire to light up the bulb." (E_{50}/11 years old) "Because the wires look the same. They just connected to different ends." (E_{79}) "The current B and A has to be the same or the light won't work. If the B side was stronger than the A-side it wouldn't work, the same if it was switched." (E_{105})

7. Objective and analyses of the data of the third question

The objective of the present question is to verify if the students are aware that if we touch the (+) and the (-) poles simultaneously we "close" the circuit then it would be deadly. The analyses of the answers can be classified into three categories described below.

7.1 Category 1: Bipolar model

It would be deadly to touch both terminals at the same time. Table 9 illustrates some pupils' responses.

Table 9.
Pupils' answers: Category 1

French pupils: 6/89	English pupils: 4/105
"If you touch both sides, you could die because it's so strong." (F_{27}) "We'll be dead when we touch both sides." (F_{28}) "Both sides because both are very hot." (F_{31})	"Neither, you would have to touch both poles to make a complete circuit to be shocked." (E_{43}) "Both ends would be deadly to touch because it is way stronger than a regular light bulb. A regular one would shock you but this one would really hurt you." (E_{105})

These pupils have not justified their answers by indicating that our body is a conductor of electric current like the wires, and we closed the circuit with our fingers on touching the two terminals. Despite this, they specified the need to use the two poles of the battery.

7.2. Category 2: Unipolar model

In this category, we have grouped the answers into three subcategories as described below.

7.2.1. Subcategory 1

It would be deadly to touch to the negative terminal. Table 10 illustrates some pupils' responses.

Table 10.
Pupils' answers: Subcategory 1

French pupils: 3/89	English pupils: 4/105
"The negative because the positive put electricity in the bulb." (F_4) "I think the (-) is going to be deadly because it's lower." (F_{20}) "The - is the answer because I have tried it before." (F_{67})	"I think the negative side would be deadlier to touch because the negative side is stronger." (E_{46}) "I think it would be the negative side because the negative side holds more power." (E_{67}) "I think negative would be deadly." (E_{72})

7.2.2. Subcategory 2

It would be deadly to touch one of the two terminals (+ or -). Table 11 illustrates some pupils' responses.

Table 11.
Pupils' answers: Subcategory 3

French pupils: 8/89	English pupils: 35/105
"I will not touch a wire because the two of them would electrocute me." (F_{36}) "It does not matter; it conducts the same volt." (F_{48}) "There is no difference." (E_{52}) "They will have the same amount of electricity." (F_{62})	"It would be deadly to touch because it is high volts." (E_3) "Yes, because the battery would be so powerful." (E_9) "I think it would be deadly to touch because 1000 volts is a lot! And it would shock you." (E_{77}) "Yes, it would be deadly to touch because of the electricity." (E_{80})

7.2.3. Subcategory 3

It would be deadly to touch the positive terminal: there is more electricity on the pole (+); there are more volts on the (+); terminal (+) is stronger than terminal (-) of the battery; the (+) had more energy, and the power comes out of the pole (+). Table 12 illustrates some pupils' responses.

Table 12.
Pupils' answers: Subcategory 1

French pupils: 26/89	English pupils: 22/105
"I think + because + has the most energy." (F_5) "(+), because that's where all the force is gone." (F_8) "I think (+) is deadly because with (+) there are more volts." (F_{11}) "I think the (+) because it gives more electricity because the (+) means more volts." (F_{15}) "It would be the (+) the deadly wire because the energy gets out." (F_{21}) "That would be the (+) side because in there, there are very large amounts of electricity." (F_{58})	"The positive end has metal which is deadly to touch." (E_{14}) "It would be deadly to touch the (+) side of the battery because that is where the power comes out." (E_{15}) "It would be a positive charge because it has more volts on that side." (E_{41}) "The positive side would be deadlier to touch because it has more voltage in it." (E_{42}) "I think is the positive side would be deadlier to touch because the positive side is stronger than the negative side." (E_{45})

7.3. Category 3

For pupils in this category, there is no danger to touch the terminals. Because the battery is not connecting with a bulb or any material that conducts the electric current, thus, no flow can circulate since the battery is not inserting into a closed circuit. Table 13 illustrates some pupils' responses.

Table 13.
Pupils' answers: Category 3

French pupils: 18/89	English pupils: 27/105
"None because you need a source of ground, but if there is a source of ground, both can kill you." (F_{16})	"If it was working it may shock you but if it isn't working it probably wouldn't." (E_5)
"If you had a piece of iron, yes it would be deadly." (F_{32})	"The battery would not be deadly because there are no wires to it." (E_{35})
"Because the poles, if it has to work, there must be a ground wire." (F_{56})	"It depends if the battery is connected to wires to be deadly. If it's connected, don't touch it." (E_{58})
"No, it will not be dangerous because there is no iron touching it." (F_{57})	"Neither pole would be deadly to touch because the electricity can't go from a battery to your body." (E_{60})
"No pole because there is no electricity in a battery." (F_{59})	
"Not a pole would be deadly to touch, only if the battery was plugged." (F_{65})	"The battery would not be deadly to touch because it has no wires hocked to it." (E_{65})
"No pole would be deadly to touch unless you touch it with metal." (F_{81})	"I don't think it would kill you because there is no energy going these." (E_{85})

After all, only nine French pupils and 13 English pupils have advanced incomplete or indecipherable explanations for grouping them into a given conceptual representation.

Conclusion and didactical impact

The results of this analysis attest to the striking parallelism between their conceptions and are like those identified in a different country. Thus, there is no significant difference between the conceptions identified, while a study conducted by the OECD (2015) indicates that English-speaking high school students in Canada perform better in science than their counterparts in minority communities. In conclusion, we will present our hypotheses to try to understand why, at the primary level, there is no significant difference while at the secondary level, we have a noticeable difference.

The analysis of the conceptions of French and English-speaking pupils shows that they share the same conceptual understandings about the concepts underlying the functioning of electrical circuits. Thus, the mother tongue does not seem to influence their conceptions. How can the results of the OECD study show that, at the secondary level, Francophones do not perform as well as Anglophones? Here are some hypotheses of answers: (1) Language requirements: Absence of textbooks in French adapted to students' language skills; (2) Teacher training: Difficulties in recruiting students from minority francophone regions by faculties of science of education; (3) Policies of Departmental Leaders on the Training of Students in Minority Environments.

The results of our research show that, in the case of electrical circuits, French-speaking pupils aged between 10 and 12 years old perform as well as the Anglophone pupils. However, we should ask them about other scientific phenomena to generalize our results. In relative terms, secondary school pupils whose Anglophone students perform better than those of Francophone Minority students should identify their conceptual representations using a qualitative methodology to understand better the difference observed by the OECD PISA (2015) research.

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