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MISCONCEPTIONS AND HISTORY OF SCIENCE IN SCIENCE-STUDENT EDUCATION: FORCE-GRAVITY AND MOTION

[1]Abdeljalil Métioui, [2]Louis Trudel
[1] Université du Québec à Montréal, Montréal, Canada
[2]Université d'Ottawa, Ottawa, Canada
[1]metioui.abdeljalil@uqam.ca

***Abstract*— The analysis of the data of the paper questionnaire that we managed to fifty eight (58) elementary school pupil's (10-12 year old) from Quebec in Canada demonstrates that their conceptions are look like those developed in the setting of the physics of the movement developed by Aristotle (384-382 av. J.-C), and the theory of the impetus developed by Buridan (1300-1358): the motion requires the continuous application of force, a force produces a movement; in the absence of a force the objects are to rest.**

***Keyword* — Conception, pupils, elementary school, laws of Newton.**

I. INTRODUCTION

The works of numerous researchers demonstrate that among the students of the elementary school (7-12-year-old), their conceptions of the concepts force and motion are naïves [1, 2] and resemble to some theories developed during history and that have been refuted since the advent of the classic mechanics developed by Newton [3]. The present communication is related to this problematic and has for objective to construct the conceptions of fifty-eight (58) elementary school pupils about the laws of Newton.

II. METHODOLOGY AND POPULATION

To identify the conceptions of fifty-eight (58) students aged between 10 and 12 years, we have given them, on a voluntary basis, a paper and pencil questionnaire of sixty minutes' duration. To complete it, they had to use their spontaneous conceptions since they have received no training on the topic connected to the concepts of motion and force.

III. PAPER-PENCIL QUESTIONNAIRE : CONSTRUCTION AND ANALYSES

The questionnaire we built covers some program concepts related to the study of three Newton's laws of motion, espacially the first (inertia) and the second (action and reaction) as well as the law of universal gravitation. Note that their study is prescribed in the curriculum of the Ministry of Education [4]. The notions prescribed in the curriculum are summarized in table I.

Note that we didn't find in the curriculum enough information about the degree of deepening of these notions, which we believe could be problematic in the case of primary teachers with science formation is deficient [5, 6]. On these notions, we construct seven questions shown in the appendix. In the following section, we will present the objectives of each one followed the analysis of responses by students.

TABLE I. THE NOTIONS PRESCRIBED IN THE CURRICULUM OF THE MINISTRY OF EDUCATION: FORCE AND MOVEMENT.

1. Describe the effect of the gravitational attraction on an object (ex.: free fall)
2. Describe the characteristics of a movement (e.g. direction, velocity)
3. Effects of a force on the direction of an object: 3.1 Identify situations where the friction force (friction) is present (pushing on an object, drag an object, roll an object) 3.2 Identifies examples of a force (e.g. pull, push, throw compress, stretch) 3.3 Describe how a force acts on a body (put it in motion, modify its movement, stops it)
4. Combined effects of several forces on an object (expect the combined effect of several forces on an object at rest or in linear movement (e.g. reinforcement, opposition)

A. Question # 1

A person who tries to displace his car that, unfortunately, doesn't move. Is there a force applies on the car? This question is intended to determine whether, for the students, several forces are applying on the car. Those forces are the muscle power that the person uses, the weight of the car (gravitation), the reaction force (Newton's third law) opposite to the gravitational force and the friction forces due to the tire contact with the ground and probably the strength of the wind. 64% of children, there is a force that is applied to the car even if it is stationary. 54% of them, this force is the one applied by the person. For them, the intensity of this force is not sufficient to overcome the inertia of the car (because the car is heavy). Only 11% mentioned the presence of a second force that is opposed to that applied by the person. However, they did not explain the origin of this frictional force (contact between the tires and the ground). Surprisingly, 11% of students referred implicitly to the strength of gravity (the weight of the car) and not muscle strength person without developing it. Finally, a significant proportion of students (36%) has advanced no response when vague answers and some have even advanced hypotheses related to the state of self to why the person is unable to move. Table II summarizes the two categories of identified responses, followed illustrative of some student responses. In the case of Category 1, four were identified subcategories.

TABLE II. CATEGORIES DERIVED FROM QUESTION 1 AND ANSWERS OF THE PUPILS

Category 1 (37/58 - 64%)

There is a force that is applied to the car even if it does not move.

Category 1.1 (20/37 - 54%)

There is a force that is applied to the car even if it does not move: the force of the person.

"Yes, because one pushes but is not strong enough to push the car. "(E7)

"Yes, if the car is not moving, because the man is not strong enough. "(E23)

"Yes, the person pushes the car, then the car has a forcer. "(E30)

"Yes, because if you push something, you use your force. "(E31)

"Yes, because the person nevertheless pushes on the car. "(E36)

"Yes, the force of the arms and legs of the person. "(E43)

"Yes, because he forces but maybe the car is too heavy. "(E44)

"Yes, because even if the car is not moving, the man deploys an effort. This means that the mass of the car is too heavy for him. "(E57)

Category 1.2 (4/37 - 11%)

There are two forces acting on the car: the person's strength and the one that is opposite to his strength.

"Yes, because if there was no force, the car would advance easily. If a force like gravity nails us to the ground, there must be a force that prevents us to advance or move some items, unless another force pushes us or pushes the object we are trying to move. "(E1)

"Yes, the wind pushes it to the other side, which prevents the moving of the car. "(E39)

Category 1.3 (4/37 - 11%)

There is a force that is applied to the car even if it does not move: the force of gravity or weight.

"Yes, because the middle of the earth is like a magnet, allowing us to stay on our feet. "(E18)

"For sure there is a force, all the things that cars include have gravity. So, there is a lot of force. "(E29)

"Yes, the weight of the car, the engine, the windows, etc. "(E38)

Category 1.4 (9/37 - 24%)

There is a force that is applied to the car even if it does not move: unreadable or incomplete justification.

"Yes, because the car is heavy and it is the tires that support it. It takes a crane to push the car for it to move. "(E13)

"Yes, but only if it is in neutral. "(E14)

"Yes, because when the car is stopped, the wheels automatically block. Example, if someone wants to steal the car by pushing it, if the wheels are not blocked, he can steal. But, if they are blocked, he will not be able to steal it. "(E16)

"Yes, just the wheels. "(E45)

"Yes, because the car weighs a lot of gas and the car needs to be solid. "(E58)

Category 2 (21/58 - 36%)

Doesn't not know, does not answer the question, indecipherable answer or incomplete answer.

"No because the car has its strength and it is not the humans that give strength to the self. "(E6)

"To me, he must have left the car on the" Park ". So, that's why the car does not move. "(E8)

"Because the car is in the first gear, so he should put it in neutral. "(E12)

"The brake, maybe it is on" Park ". "(E24)

"The car's brakes, if you want the car to advance, you have to take it off the neutral. "(E25)

"It is the strength of the automatic brakes that block the car." (E35)

"Surely not, it remains stable because the engine is not running. "(E37)

"No because the battery is at zero. "(E40)

"No, a human cannot move a car because a car does not have the same force as a human. "(E42)

"The arm brake cannot be operated. "(E48)

"No. Because in the car has no more gas or the car doesn't function anymore. "(E52)

Question # 2

On a sunny day without wind, a child moves on its bicycle along a strait road (without a slope). When he ceases to peddle and without using his brakes, the bicycle continues to move going slower during a certain amount of time. According to you, is there still a force that is applied to the bicycle during its slower movement? With this question, we wanted to know how the child explains the movement of a bicycle straight after you stop pedaling. When the child stops driving, the bike acquires a certain speed, and according to the law of inertia, it will continue to move at that speed and in a straight line, by Newton's first law of motion. In the absence of an external force, it will continue its movement, but it will eventually stop because of the presence of the forces of friction between the tires and the ground. 47% said the presence of force: (1) gravity (15%), (2) the pressure force that the child has applied on the bicycle (52%) or (3) the force that the child has applied on pedaling (22%). For these last ones, their conception is like that developed within the impetus Buridan's theory. Finally, for 21%, no force is applied to the bicycle when the boy ceases to peddle (this conception goes in the absence of friction), 15% does not use the data of the problem and 17% advance vague answers. Thus, no student referred to the friction force between the tires and the ground. Table III summarizes these different categories and the student responses.

TABLE III. CATEGORIES DERIVED FROM QUESTION 2
AND ANSWERS OF THE PUPILS

Category 1 (27/58 - 47%) There is a force applied on the bicycle.
Category 1.1 (4/27) - 15%) There is a force applying on the bicycle: the force of gravity. "Gravity is a force that makes it stand on the floor. If the street or location is sloped, the bicycle will come down and if it is right, it will advance a few cm and the person will lose balance and fall. "(E22) "The force of gravity. "(E23) "Yes, the earth's gravity. "(E27) "I'm not sure but I think that the Earth is not equal everywhere, there are bumps and that the bicycle drawn through the center of the Earth is like a magnet. "(E13)
Category 1.2 (14/27) - 52% There is a force acting on the bicycle: the pressure force that the child she carries on through its "weight." "His weight pressure on the bicycle. "(E48) "Yes, I think so because when you are getting, it makes a pressure if you lean forward. "(E20) "The child's weight is going to move the car. "(E35) "Yes, the child who is on the bicycle puts a force (weight) on the bike. "(E38) "Yes, the body force is exerted on the bicycle. "(E43) "The wheels roll and it feels that your weight moves the wheels. "(E47) " Yes. When the child sits on his seat, he exerts pressure, force. "(E55)
Category 1.3 (9/27) - 33% There is a force acting on the bicycle: the force that the child has applied pedaling. "Yes, human strength. If there were no force, bicycling would not advance. "(E1) "If he just pedals, the wheels turn again, then advance. "(E10) "Yes, the bicycle will move forward anyway. "(E15) "Because the strength of his feet is still not all used. "(E25) "He pedals for a while and then stops the movement. Its wheels continue to turn for a while, then stop in turn. "(E37) "Yes, it advances. When the little man pedaled, he pedaled fast enough to stop and then move forward. "(E11) "Yes, because if there were no force, the bicycle would not advance. "(E54)
Category 2 (12/58 - 21%) There is no force because the child does not pedal and it does not wind. The students do not involve the movement of the bicycle to the application of strength. "No, I think if there is no wind, it does not force on the bicycle. "(E4) "Because the wind makes us more force, so when it is not windy, it's as if no one was blocking us. "(E12) "No. Because the child doesn't pedal, no brakes, and no wind. "(E28) "No. Because there is no wind, the bicycle can not advance. "(E39) "No, for there is a force, you need to pedal. "(E53)
Category 3 (9/58 - 15%) Not applicable data problem. "Yes, because he has to pedal to the bicycle advance. "(E21) "Yes, because it goes down a mountain or a hill. "(E41) "Yes, the wind. "(E50) "Yes, when it comes down to a bicycle coast, the wind is stronger. "(E58)
Category 4 (10/58 - 17%) Answer indecipherable. "Yes, there is a force, the child sitting on the bicycle projects a sense of balance. "(E9) "No. To have force, one must have a lot of power. "(E57) "Because the wheels are round. Then there is no force. "(E40)

Question # 3

Let's suppose that an object moves under the action of several forces. If one removes them all, it will slow down and will stop. True or false? This question associated with the first Newtonians law of motion (law of inertia) in which the rectilinear movement at constant speed requires no force. Thus, the object will continue to move with the speed he had at the moment we have removed all the forces applying on it. The analysis of the data has permitted us to identify three categories of answers. In the first one, we regrouped the students according to which the movement of the object will slow and will stop when removing all forces (21%). For them when we removed them, the object continues to move for a brief instant and stops. This conception is correct only in the presence of friction. In the second category, we regrouped the student for who the object will stop at the moment we remove all forces (67%). For these students, the movement requires applying continuous force. This conception is like which developed by Aristotle. Finally, in the third category, we regrouped student didn't give any explication or vague answer (12%). Table IV summarizes these different categories and the student responses.

TABLE IV. CATEGORIES DERIVED FROM QUESTION 3
AND ANSWERS OF THE PUPIL

Category 1 (12/58 – 21%) If we remove all the forces it slows and stops: the object

slow because the strength decreases and eventually stopped.
"True because the weight that forces gave decreases gradually and slow the movement of the object and stop. "(E20)
"True because it can not stop instantly. "(E23)
"True, it's as if I pedal my bike and pedal very quickly, and I stop driving, the movement of the bicycle slow down and stops. "(E41)
"True, when the force decreased, the object slows. "(E53)

Category 2 (39/58 - 67%)
When removing, all forces the object will stop because the movement requires the application of strength.
"Yes, because these are the forces that move the object. If there is no force to move the object, then it will stop, right? "(E1)
"It will stop because it needs force to move forward and then we remove it, then it could not move forward. "(E2)
" True. I believe that if this object needs strength to work and that if we take away these forces, it will stop. "(E9)
"True, when we move an object, we give force, so if we not give, it will stop. "(E29)
"False if we had the same experience with a wardrobe, it will stop when you do shoot more. "(E33)

Category 3 (7/58 - 12%)
When removing all forces, the movement of the object will slow and stop: No justification or vague answer.
"True, but I do not know why. "(E24)
"True because the force of gravity and the ground clearance the object will stop because it will rub against the ground. "(E32)
"False. It will advance faster. "(E48)

Question # 4

When one applies a constant force on an object, will it move to a constant speed? This question is constructed to see what relationship students develop the concepts of force and speed. According to Aristotle's conception of motion, the force is proportional to the speed. Since Newton's work on the movement, we know that the force is rather proportional to the acceleration (the rate of change in velocity). Thus, in Newtonian's view when the resultant force applied to a given body is null, the object moves in a straight line at a constant speed or is not moving (First law of Newton: Inertia). Table V summarizes these different categories and the student responses.

TABLE V. CATEGORIES DERIVED FROM QUESTION 4 AND ANSWERS OF THE PUPIL

Category 1 (30/58 - 52%)
When one applies a constant force on an object, it will move at a constant speed.
"Yes, because we applied a constant force on the object. "(E17)
"Yes, because if I push the object, for sure it will go at the same speed as I pushed. "(E23)

Category 2 (20/58 - 34%)
When applying a constant force on an object, it will not move at a constant speed because it will depend on its weight.
"It depends on the object. If it's an eraser yes, but if it is a bus, no. "(E14)
"No, because if the object is heavy and you will put all your strength, it will not advance more quickly. "(E15)
"Yes, if the object is as your size because it will go to the same speed as you and no if it's bigger because it will be heavy. "(E20)

Category 3 (8/58 - 14%)
No response or indecipherable answer.

Question # 5

According to you, do the astronauts have the same mass on the moon than on the earth? The purpose of this question is to check whether students differentiate between mass (amount of matter) and weight (gravitational force). The analysis of student responses reveals two categories of response. The first category (14%) represents those whose answer is correct (the astronaut has the same mass). However, they did not provide any explanation for their response. As for the second category, according to which the mass of the astronaut is not the same (86%). The justifications put forward are grouped in five subcategories which are: 1. The absence of gravity on the Moon (32%); 2. In space, we float (24%); 3. Lack of air in space (16%); 4. On the moon we are lighter (16%); 5. The mass of the Moon is different than the mass on the and Earth (12%). Table 6 summarizes these categories as well as student responses.

TABLE VI. CATEGORIES DERIVED FROM QUESTION 5 AND ANSWERS OF THE PUPIL

Category 1 (8/58 - 14%)
Correct answer without justification: the astronauts have the same mass on the Moon than on Earth.
« Yes, because on the Moon and on Earth astronauts have the same mass. » (E52)

Category 2 (50/58 - 86%)
Wrong answer: astronauts do not have the same mass on the Moon than the Earth.

Category 2.1 (16/50 - 32%)
Astronauts do not have the same mass on the Moon than the Earth because in space there is no gravity.
"No, because in space there is no gravity. " (E1)
"No! This mass projects them into the air, it is called the state of weightlessness."(E9)
"No. Because in space you are in zero gravity. "(E23)
"No. On earth, we have gravity but not in space. "(E26)
"No because on Earth there is a force called gravity that

retains them. But on the moon, there is no gravity. "(E40)
"Well no. On the moon, they have no gravity while on Earth they have weight. "(E45)
"No in space, there is no gravity. "(E46)

Category 2.2 (12/50 - 24%)
Astronauts do not have the same mass on the Moon than on the Earth because they float in space.
"No, they are lighter, that's why they put on a heavy suit. They put on so they don't fly. "(E5)
"No since the Moon is in space and in floats. "(E20)
"No. Because in space one flies over but on earth one walks and if one try to fly it is because one has a problem."(E24)
"No gravity of the Earth is different from that of the Moon. On Earth, we stay on the ground and on the Moon, we float. "(E37)

Category 2.3 (8/50 - 16%)
Astronauts do not have the same mass on the Moon than the Earth because in space, there is no air, oxygen, etc.
"No, because there is no air, no gravity. "(E24)
"Not because on the moon is empty we cannot live forever. There is no air. "(E29)
"No, because they do not have the weight of the air on their shoulders. "(E41)
"No, because in space there is no oxygen, the astronauts and objects are weightless. "(E49)

Category 2.4 (8/50 - 16%)
Astronauts do not have the same mass on the Moon than the Earth because they are much lighter on the Moon.
"No on the Moon they are less heavy."(E2)
"No, they are much lighter on the moon. "(E33)

Category 2.5 (6/50 - 12%)
Astronauts do not have the same mass on the Moon than on the Earth because of gravity or because masses of the Earth and Moon are different.
"No on the Moon the direction of gravity is not the same as the one on Earth. "(E25)
"No since the mass on the moon is different than ours. "
"No, the fact of gravity on the moon is smaller than on Earth. "(E48)

Question # 6

When a golf player throws his ball, is there a force that applies to it once it is launched? This question relates to whether for students, the force applied by the player maintains the movement of the ball for a while. This view is erroneous and is like that developed by Buridan's theory of impetus: when a player throws his golf ball after the ball is throw, the applied force is transferred to the ball. 36% of students share this view. For other students (27%), their conception is like that developed by Aristotle, who advances that the movement of the ball is due to the presence of the air. This understanding is wrong because forces applied on the ball are: the gravitational force and the force due to the movement of air. Table VII summarizes these different categories and the student responses.

TABLE VII. CATEGORIES DERIVED FROM QUESTION 6 AND ANSWERS OF THE PUPIL

Catégorie 1 (45/58 – 78 %)
When a golf player throws his ball, there is a force that applies to it once it is launched.

Catégorie 1.1 (12/45 – 27%)
When a golf player throws his ball, there is a force that applies to it once it is launched: The force of the wind
"Yes, the wind pushes since it is light." (E8)
"The air since it is not very aerodynamic, air produces a pressure on the ball." (E48)
"Yes, because the wind blows and the ball did not always go in the same direction." (E50)
"No, because the air pushes the ball not the force." (E51)
"Yes, because the ball flies through the air. Over it flies, the more the wind is high." (E58)
"No, because the air pushes the ball not force." (E51)

Catégorie 1.2 (16/45 – 36%)
When a golf player throws his ball, there is a force that applies to it once it is launched: **The force applied by the player**
"Yes, the force that the player put above to strike it." (E3)
"Yes, the strength he has given for the launch." (E15)
"Yes. The force that the man applies to launch it." (E16)
"Yes, because the force applied by the player makes the ball continue to fly in the air." (E18)
"This is the strength of the player because he wants the ball to go further." (E24)
"Yes, because the strength which a player puts [applies] on the ball is very high." (E29)
"Yes. When the ball launched, it will travel with the strength of the golfer, and there will be pressure on the ball." (E33)

Catégorie 1.3 (6/45 – 13%)
When a golf player throws his ball, there is a force that applies to it once it is launched: **The force of gravity**
"Yes, the force of gravity because the ball will descend." (E21)
"Yes, the force of gravity." (E23)
"Yes. The gravity." (E27)
"Yes, the force of gravity otherwise the ball fly and could go around the world several times." (E3

Catégorie 1.4 (12/45 – 27%)
When a golf player throws his ball, there is a force that applies to it once it is launched: Incomplete or indecipherable explanation

Catégorie 2 (8/58 – 14 %)
When a golf player throws his ball, there is not a force that applies to it once it is launched.
"No, because it is at the beginning that the force is applied. "(E4)
"No ! The force was when the player launched the ball."

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(E9) "The force is applied to it in contact with the stick but I think when it is in the air, it is only the power of his stick." (E22)
Catégorie 3 (4/58 - 7 %) No answer

Question # 7

Is it always true that when one pushes an object (a piece of furniture, for example), more one pushes high and more it advances quickly? This statement is not always true. Indeed, if the friction between the piece of furniture and the ground is reduced, we will push less, and the object will move faster. No student has elaborated on the friction force that opposes the movement. Table VII summarizes these different categories and the student responses.

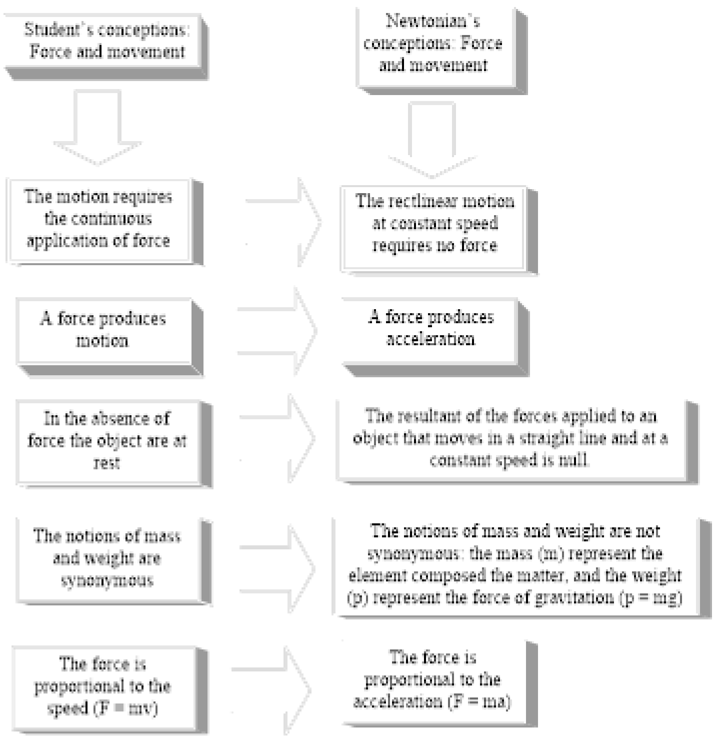
TABLE VIII. CATEGORIES DERIVED FROM QUESTION 7
AND ANSWERS OF THE PUPIL

Category 1 (39/58 – 67 %) It is always true that when one pushes an object, more one pushes high and more it advances quickly
Catégorie 1.1 (11/39 – 28 %) It is always true that when one pushes an object, more one pushes high and more it advances quickly: No justification or claims not to know why.
Catégorie 1.2 (28/39 – 72 %) It is always true that when one pushes an object, more one pushes high and more it advances quickly: The more strength, more an object will move faster. "Yes, because fact to push more hardly made that we face the strength which prevents the piece of furniture to move." (E1) "Yes. If we give small forces to push an object, it will move forward. However, if we give bigger forces to push an object, it will move forward faster because we push higher." (E10) "Yes. The force which you applied to push the piece of furniture moves it. And if you used more force to push the piece of furniture, it would go faster." (E14) "Yes, because if we push on the object slowly, it is going to go slowly, if we press high, it is going to go faster, etc." (E21) "Yes, because if we push more high, the object will move more quickly because the strength is faster." (E22)
Category 2 (6/58 – 10 %) The object will not go necessarily faster if we force high it depends on its "weight".
Category 3 (9/58 – 16 %) Indechifrabe or incomplete answer
Category 4 (4/58 – 7 %)) No answer

CONCLUSION

In conclusion, we identified four erroneous conceptions: (1) the motion requires the continuous application of force, (2) a force produces motion, (3) in the absence of force the objects are at rest; and (4) the notions of mass and weight are synonymous. These conceptions and those developped during history are interesting to crate many constructivist environments for teaching. We will present, some environments that take account the conceptions identified in this research and those developed during history as summarized in table VIII. These environments appear in a constructivist perspective centered on the notion of conceptual change [7]. These false representations should normally be change following a formal training, but several works demonstrate that they persist to the teaching [3, 8].

TABLE VIII. SUMMARY OF STUDENTS' CONCEPTIONS AND OF THEIR CORRESPONDING SCIENTIFICALLY ACCEPTED COUTERPART.



REFERENCES

[1] Hast, M., and Howe, C. (2012). Understanding the beliefs informing children's commonsense theories of motion: The role of everyday object variables in dynamic event predictions. Research in Science & Technological Education, 30, 3-15.

[2] [2] Watts, M., & Zylbersztain, A. (1981). A survey of some children' s ideas about force. European Journal of Science Education, 16, 360-365.

[3] [3] Sequeira, M. and Leite, L. (1991) Alternative conceptions and history of science in physics teacher education. Science Education, 75(1), 45 56.

[4] [4] Government of Quebec. (2017):

[5] http://www1.education.gouv.qc.ca/progressionPrimaire/science/

[6] [5] Métioui, A., Trudel, L., and Baulu MacWillie, M. (2015). Preservice primary teachers' representations after teaching of the elementary electrostatic phenomena, International scientific on-line journal ″Science & Technologies″, Publisher "Union of Scientists - Stara Zagora", Volume V, Number 3: Natural and Mathematical science, 115-120.

[7] [6] Appleton, K. (2003). How Do Beginning Primary School Teachers Cope with Science? Toward an Understanding of Science Teaching Practice. Research in Science Education (2003) 33: 1.

[8] [7] Gunstone, R. (Editors) (2015). Encyclopoedia of Science Education :

[9] DOI 10.1007/978-94.

[10] [8] Métioui, A., and Trudel, L. (2015). The persistence of the alternative conceptions: The case of the unipolar model (pp. 117-127). Proceeding of the GIREP-MPTL 2014 International Conference, July 7-12, University of Palermo, Italy: Teaching/Learning Physics: Integrating Research into Practice, C. Fazio and R.M. Sperandeo Mineo (Eds.).