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Magnetic field mental representations of 15-16 year old students

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ABSTRACT

The study of students' mental representations of Natural Sciences concepts and phenomena constitutes a central part of Physics Education research, as they play a decisive role in teaching. In the study presented here, we investigate 112 15-16 years old students' mental representations of the magnetic field, after they were taught about it in school. The empirical data was gathered through an interview using 3 tasks which involved the evaluation of actual or hypothetical situations. The research data included mental representations that cause difficulty in the comprehension of the properties of the magnetic field.

Indexing terms/Keywords

Magnetic field, representation, secondary education

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INTRODUCTION AND THEORETICAL FRAMEWORK

A countless part of the research in Physics Education concerns the study of different age children's mental representations about the formation of concepts as well as their representations about phenomena of the physical world (Gilbert & Watts, 1983; Koliopoulos & Ravanis, 1998; Dedes & Ravanis, 2009a, 2009b; Rassaa, 2011; Hammer, Goldberg & Fargason, 2012). This perspective, which consisted of the initial point for the constitution of this scientific field, changed the view about the evolution of teaching processes. Actually, the study on children's 'conceptual world' brought to light the crucial role of mental representations which are shaped in children's thought in a phase before teaching intervention, as well as subsequent to it. According to this prospect, quite a few researches study students' representations as well as the effort to transform them into representations carrying aspects compatible with the specific descriptive and functional characteristics of scientific models. Both in the two directions, in the area of magnetism with which we deal with in this study, the relative researches are limited.

Mental representations, being the product of the individual and social history of the child, are in continuous interaction with the socio-cultural and educational environment and as such, present a dynamic, developmental and evolutionary nature. Thus, insofar as the representations through which the child interprets the phenomena of the physical world are remote or in contradiction with certain elements of scientific models currents dominant of Physics Education research, aim at the construction of educational interventions, teaching situations and curricula that may foster the crossing designs and the explanatory mental forms of naive representation implied, local and non-conscious concepts or phenomena (Koliopoulos & Ravanis, 2000; Kampeza, 2006; Ravanis, Koliopoulos & Boilevin, 2008).

Simple magnetic behaviours constitute a cognitive area that has not been sufficiently studied, since related research is limited. These behaviours are the result of the magnetic field but, on the level of the students' thought process, they also certify its existence. That is to say, a magnet exerts forces on another, smaller magnet when the latter comes in the vicinity of the first. This event, incompatible with empiricism of that era, caused difficulty in its interpretation. It should be noted that this question had raised many arguments among physicists in 18th century in terms of providing a context of its interpretation. In order to overcome this conceptual problem of forces acting from a distance, Michael Faraday (1791-1867) introduced the concept of the "field". He proposed that the presence of a magnet at a point in a previously empty space, changes the properties of this space. This means that an invisible entity – a magnetic field – is created around the magnet (Gillespie, 1960; Pocovi & Finley, 2002). Therefore, one may consider that the second, smaller magnet interacts with the magnetic field with which it is in contact, rather than with the first magnet from which it is far apart. So then the magnetic field appears and establishes its existence through a series of interesting properties, some of which we will be studying in this paper.

The research of Piaget & Chollet (1973) showed that, as children discover magnetic forces, up to the age of seven they attribute them to an intrinsic property of the material which "sticks" in the case of attraction and "blows" in the case of repulsion. Later, up to the age of ten, the explanations of children are in terms of "forces" or "streams" which attract or repulse. Up to the age of fourteen, children attribute magnetic properties either to the discharge of "molecules" or "little pieces" of the magnets, or else to forces propagated by means of "a kind of gravity", "a kind of electricity", "pressure of air", "magnetic streams", "a kind of lighting", "rays" or "heat", that is, concepts deriving from everyday life or education.

The fundamental magnetic properties can become an object of study between the ages of 4-6. Related researche projects found that, within an organised environment that favours experimentation, a large number of children of this age discover the forces of attraction of magnets on metal objects and the forces of attraction and repulsion between magnets, while they also start to learn which substances are attracted by magnets and which are not (Ravanis, 1994, 1996; Tsatsaroni, Ravanis & Falaga, 2003; Papadopoulou & Poimenidou, 2008).

A study of students aged 9-18 focused on issues of understanding action at a distance (Bar, Zinn & Rubin, 1997; Bar & Zinn, 1998). The results of this study showed that 4 in 5 students aged 9 consider air necessary for the exerting of magnetic forces, a proportion that is gradually reduced, becoming 1 in 3 in the case of 18-year-old students. This study also found that children see links between magnetic and gravitational phenomena. These links may go as far as mental representations acknowledging magnetism as the cause and gravity as the effect.

In a study of students aged 9-14, an attempt was made to create general models for approaching magnetic phenomena (Erickson, 1994). The first model, the "pulling magnet" is used by younger students to describe the effect of magnets on bodies that are close by, but without indicating the underlying reasoning that would explain or interpret these magnetic behaviours. In the "emanating model", magnetic phenomena are attributed to the emission of energy or to rays directed from the magnets to the bodies being attracted. The third one, known as the "enclosing model", acknowledges the existence of an area of influence surrounding the magnet, thus adopting a representation which refers to a naïve image of the magnetic field.

The classification of the conceptions of students aged 15-18 was also attempted in research performed by Borges and Gilbert (1998). Here, the students' conceptions were classified into 5 different categories. The first and the second refer to Erickson's first and third model, while the third category comprises conceptions that link magnetism to electricity, given that the magnetic poles show an accumulation or a deficit of positive or negative charges. The fourth category consists of the conception that magnetic phenomena are caused by electric dipoles that are formed into the magnet as a whole. Thus, one of the magnet's poles displays a positive charge while the other displays a negative one. In the fifth category, the descriptions of the interactions refer to a certain kind of magnetic field similar to the one described in formal school textbooks. But the children that use this reasoning can offer explanations on a microscopic level, alternately using the concept of elementary magnets and the concept of cyclical micro-currents.

Bradamante and Viennot (2007) tried to link magnetic and gravitational sources with their respective field lines and then use this linkage to differentiate between the two kinds of interactions. This study showed that the proposed "mapping" and the differences between the maps are accessible to a large proportion of students aged 9-11.

Research carried out by Ravanis, Pantidos and Vitoratos (2009, 2010) studied the mental representations of students aged 14-15 in regard to the magnetic field. The study of the children's mental representations was carried out through interviews performed at the end of lessons involving magnetism and electromagnetism in the students' classrooms. The children were given 3 consecutive tasks. A discussion then developed based on these tasks. From the total results, it appears that 7 to 9 out of 10 students undertaking each task face considerable difficulty in handling the characteristics and properties of the magnetic field.

Finally, the research of Voutsina and Ravanis (2011, 2013) study the mental representations of students aged 15-17 concerning action at a distance based on the manner of transfer of the magnetic force as well as the relation between magnetism and gravity. The research was carried out using structured interviews with a total of 40 students from the 10th and 11th grades. The work also attempt to study whether the students' representations show an analogical reasoning with typical historical models of the Sciences and whether there exist differences related to conventional school teaching. The results indicated points where students' representations appear to approach basic elements of historical models of the Sciences.

In the research presented here, we have tried to study the mental representations of ninth grade students regarding the comprehension of the basic properties of the magnetic field as they are approached within an educational context.

METHODOLOGY

Subjects

One hundred twelve 15-16 years of age coming from 6 different school classes, took part in this study. It should be noted that students are taught topics related to magnetic field during the primary and secondary education. Students participated in the study directly after having been taught the relevant topics at school. Each socio-economic level (low, moderate, high) and all levels of students' performance (low, moderate, high) are represented equivalently in the sample.

The researche procedure

The study of students' representations carried out through directive individual interviews and took place in laboratory classrooms. Each interview lasted 20 minutes approximately and it was conducted after the end of the teaching interventions about magnetism and electromagnetism in students' classrooms. As teachers so students were not informed that interviews would take place at the end of teaching interventions. We proposed to students three (3) experimental tasks. The interviews were based on these tasks, and the conversation was centred on students' conceptual constitution about magnetic field. In the discussion which follows we present the questions, the experimental tasks and some of students' typical answers. We also present a categorization of students' ideas as well as the frequencies that these are appeared.

TASKS AND RESULTS

The introduced tasks did not have any purpose to seek from children to recall or to reproduce the declarative knowledge which they had been elaborated in school lessons. That happens because such a perspective – which is strong confined by the modes of expression that students use - would record just the mental representations influenced by the work into the classroom. By using these tasks, we tried to investigate whether, after the teaching intervention, the students can formulate thoughts which exploit the concept of the magnetic field satisfactorily. These tasks do not lead to one-way answers such as "right-wrong", but to contexts of conversation which allow the formulation of alternative answers. Indeed, during the elaboration of students' responses, by making different assumptions, it is possible different solutions in the specific problems to be arose.

The tasks

Task 1. "A magnet is over a table. When we move a metallic object very close to it, such as, for example, a nail, the object is attached to the magnet. Why does this happen? We remove the object in a distance from the magnet, we leave it on the table and then we observe that the object stays immobile. What exactly happens?"

Through this simple experimental situation we attempt to detect if the children understand the exertion of magnetic forces in the context of the magnetic field; if students correlate (and how) the change of the intensity of the magnetic field with the distance from the magnet; if they associate the displacement of the object with the all exerted forces. Actually this specific task sets the question if the action of the magnetic field can be connected with the rest entities of the environment of a simple experimental situation.

Task 2. We present to the students a figure and we give them the following clarifications. "In the identical trolleys T_1 and T_2 there is a piece of iron and a magnet which have the same mass. The two trolleys are strong joined with a wooden stick, while we consider that any kind of friction between trolleys and the ground is negligible. If we disconnect and move the stick away, please describe and explain what will happen. Shall some of the objects move? If you do not believe that, you have to explain your answer. If you believe that some of the objects are going to move you have to describe their motion explaining your view too".

Through this task we attempt to find out if the children can understand the magnetic field as a space in which some specific interactions take place and not as a region in which the magnets exert forces in metallic objects. That means we tried to investigate if the children's thought as regards the magnetic field and the magnetic forces conveys the typical characteristics of fields and of forces exerted from the fields.

Task 3. "In a transparent airproof container, two magnets which are hanged in the air by threads fastened in the ceiling of the container are attracted to each other being in touch. By using a vacuum we remove the air from the container. Taking into account that there is no air in the container how these two magnets are going to perform?"

Through this thought experiment we attempt to detect if the children connect the magnetic interaction with the existence of the air considering the air as a necessary mean for the activation of the magnetic field.

The results

Task 1. From discussions we had with children we schematized three sorts of answers which, some of them just describe the experimental situation, but, some others convey a systematic analysis of the forces exerted to the material object (Table 1).

(a) Answers in which the position that the object takes each time, is systematically analyzed in terms of exerted forces in the context of the magnetic field as well as of friction. For example, "If they can overcome the friction .... they will move one towards the other access .... The attractive forces are reciprocal" (Subject 33).

(b) Answers in which an implicit mention is made, concerning how strong the magnetic field is, in relation with the distance from the magnet. For example, "The nail is far away .... the magnetic field does not extend till there… (R. In which distance is it extended?) …I do not know….. the exact point but this is not the point that you had put the nail" (S.101).

(c) Answers in which students mention "the force of the magnet" or/and "the weight of the object". For example, "Because the magnet has no force to pull the nail" (S. 89), "…The nail is far away…… for this magnet…." (S. 21).

Table 1. Frequencies of answers of subjects on the first Task

	Frequencies	Percentages
(a) Take into account all the exerted forces	16	14,2
(b) Mention the magnetic field	55	49,1
(c) Consider the weight of the object or/and the distance from the magnet	41	36,7

Task 2. The types of reasoning that children formulate in this task, indicate that since students deal with an unfamiliar for them situation, quite a few difficulties as regards the approaching of forces of interaction in the magnetic field, occur. Here, three sorts of answers arose (Table 1).

(a) Answers through which the students predict correctly the interaction and the simultaneous approaching of both vehicles. For example, "… The magnet will pull the iron body….. also the iron body will pull the magnet and the two trolleys will be moved … and they will crash about in the central… (R. Why?)… Because of action and reaction" (S. 11).

(b) Answers in which, although the students provide a sort of intuitive solution of the problem, they can not explain their thought in terms of interaction. For example, "The magnet will pull the iron body which is carried by the trolley … but also it [the magnet] will be moved towards the body …but since the stick is removed the trolley which carries the magnet will be also moved……… But I do not know how this is done ..... Is it some other force? (S. 76)

(c) Answers through which the students recognize that the magnet will merely exert an attractive force to the iron object. For example, "The magnet will pull the iron object and therefore……. the vehicule which carries it, will roll… (R. Will the magnet be moved?) … The magnet…….. I don't think……. because there is nothing to pull the magnet" (S. 18).

Table 2. Frequencies of answers of subjects on the second Task

	Frequencies	Percentages
(a) Forces of interaction	18	16,1
(b) Motion of the vehicles with no explanation	12	10,7
(c) Exerting of a force and motion of the iron object	82	73,2

Task 3. The types of reasoning that children express in this hypothetical task are related to, whether or not children recognize significance in the role of the air. Besides, quite a few number of children support that they do not know (Table 3).

(a) Several students recognize that the existence of the air is not connected with the magnetic interactions. For example, "The magnets will remain together… the air does not have any relation with the magnetic force… the air does not affect anything (S.33).

(b) On the contrary, some students declare that the existence of the air is necessary for the forces to be exerted. For example, "…I believe that the magnets will unstick… they will cease to be attracted since there is no air… because I believe that the magnetism is carried through the air…" (S.69).

(c) Students who are unable to formulate a response.

Table 3. Frequencies of answers of subjects on the third Task

	Frequencies	Percentages
(a) The magnetic forces do not depend on the air	46	41,1
(b) The magnetic forces depend on the air	60	53,6
(c) Unable to formulate a certain answer	6	5,3

DISCUSSION

According the results deriving from the three tasks, it seems that students face quite a few and important difficulties as regards the conceptualization of the magnetic field.. Except the task related to the propagation of the magnetic field into the air in which 4 out of (10 students approximately correspond correctly, in the rest of the tasks only 1 out of 8 students approximately can deal with the situations accurately. This, is not connected only with the insufficient understanding of the magnetic properties but also is related with the students' weakness to correlate characteristics of the magnetic field with the rest characteristics of the experimental situation. Really, in the Tasks 1 and 2, two aspects of exerted forces by distance, that is to say, the change of the value of the attractive forces as long as we go away from the magnet, and the exertion of interactions into the magnetic field, are closely connected with issues like the estimation of the conditions under an immobile body may be moved since some forces are exerted (Task 1), or like the action-reaction issue (Task 2). Consequently, we could lay stress on organizing appropriate teaching activities for the better understanding of the magnetic field, but also, on re-organizing some aspects of the curricula in order the study of the magnetic properties to be thoroughly connected with issues concerning the Newtonian model.

Therefore, it is very important for us, to underscore the distance between the theoretical knowledge about the magnetic field and its properties, and the areas that this knowledge can be implemented. This dimension is significant in the context of re-examining the teaching practices, since students who participated in the specific research had already completed a first full circle as regards a qualitative approach about magnetic and electromagnetic phenomena; for that reason we expected better results concerning the comprehension of magnetic properties.

In this perspective we need to study thoroughly all aspects of the students' representations about the magnetic field and its properties, their evolution as regards teaching, as well as to exploit the international research experience regarding issues of teaching and learning of magnetism.

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