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MAGNETIC FIELD MENTAL REPRESENTATIONS OF 14-15 YEARS OLD STUDENTS

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Abstract: Children's mental representations about physical concepts and phenomena play a vital role in the learning process. This is confirmed by the data derived from relevant researches which demonstrate that the students formulate incompatible ideas compared with the scientific ones. In this research we investigate the representations of 14-15 years old students about the magnetic field. One hundred and sixteen students participated in the research and the directive individual interview was the technique that we used to collect the empirical data. The results indicate that the children face difficulties in the comprehension of the nature as of the properties of the magnetic field.

Zusammenfassung: Die Geistesdarstellungen der Kinder bezüglich Begriffe und Phänomene, die mit der Umwelt zusammenhängen, spielen eine lebenswichtige Rolle im Lernprozess. Dies wird durch Daten bestätigt, die von relevanten Studien abgeleitet werden und aus denen hervorgeht, dass die Schüler bezüglich der Naturerscheinungen inkompatible Ideen formulieren, wenn sie mit den wissenschaftlichen verglichen werden. In dieser Studie werden die Geistesdarstellungen über das Magnetfeld bei Schülern im Alter von 14-15 Jahren erforscht. Einhundertsechzehn Schülern nahmen insgesamt an dieser Studie teil und durch gesteuerte Interviews von jedem einzelnen Teilnehmer wurden die empirischen Daten eingesammelt. Die Resultate zeigen an, dass die Kinder Schwierigkeiten im Erfassen der Natur sowie der speziellen Eigenschaften des Magnetfeldes haben.

Key words: magnetic field, representation, secondary education

1. The research framework

A great part of the research in Science 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. Ravanis & Koliopoulos, 2007. Resta-Schweizer & Weil-Barais, 2007. Ravanis, 2008). 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.

The magnetic field reveals itself by following a range of interesting properties: forces that are exerted from a distance, attractive and repulsive forces, effects from electrophorous conductors, detection of earth's magnetic field etc. The first attempt for studying the children's thought concerning magnetism made by Piaget and Chollet (1973) who found out that children seven (7) years of age, by discovering the magnetic properties of a material, attribute the attraction to the internal property of "gluing", and the repulsion to the "blowing". Later, till ten (10) years of age approximately, children's explanations turn to attractive or repulsive "forces" or "streams". At the age of fourteen (14) the children attribute the magnetic properties either to the flow of "molecules" or of "small pieces" from magnets, either to forces propagated through "a sort of gravitation", or "a sort of electricity", through the "pressure of the

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air", "magnetic streams", "a kind of lighting", "rays" or "heat", that is to say, concepts which come from the daily life or from the educational context in general (Vamvakoussis, 1984).

In a research with pre-service teachers of the primary education, Papamichael and Ravanis (1993) recorded the teachers' mental representations as regards the elementary magnetic properties; the results of the research showed a great differentiation from scientific models. Indeed, although the teachers had already attended multiple cycles of lessons about magnetism and electromagnetism, 7 out of 10 approximately could not recognize the simultaneous interactions among magnets and metals which are both located into magnetic fields. Besides, 6 out of 10 teachers did not understand that magnets, which are produced by the breaking of other magnets, conserve both of two poles. Finally, 7 out of 10 teachers claimed that if a metal is placed into a magnetic field then, the field will magnetize it permanently.

Bar, Zinn and Rubin (1997) and Bar and Zinn (1998), in researches conducted with students 9 to18 years of age, investigated questions concerning the students' comprehension about forces exerted from a distance. Thus, they found out that 4 out of 5 students, nine years of age, believe that the air is a necessary mean in order magnetic forces to be exerted. This proportion is gradually decreased by approaching 1 out of 3 as regards the students of eighteen years of age. Also, in the same research, children closely connect magnetic with gravitational phenomena. Such correlations, sometimes construct specific conceptual representations which recognize magnetism as a 'cause' and gravity as an 'effect'.

Empirical data extracted from students 9 to 14 years of age, led Erickson (1994) to formulate three models for the approaching of magnetic phenomena. The model of "pulling magnet", which is used by younger students, describes the effect of the magnets in bodies that are located close to them; this model, however, does not disclose any reasoning of explanation or interpretation of the magnetic performances. In the second one - the "emanating model" - the magnetic phenomena are attributed to the emission of energy or to the rays directed from the magnets to the attracted bodies. In the third model – "the enclosing model" – the existence of an area around the magnet is recognized, that is, a representation is adopted which refers to a naïve approach of the magnetic field.

In the research of Borges and Gilbert (1998) which was conducted with students 15-18 years of age, the students' conceptions are classified into 5 different categories. The first and the second one correspond to the first and to the third model of Erickson's study, while, in the third category the magnetism is correlated with the electricity in terms of accumulating or showing a deficit of positive or negative charges in the magnetic poles. In the fourth category an assumption is formulated, that is, the magnetic phenomena are attributed to electrical dipoles contained into the magnet, which are oriented properly so that the one pole to be charged positively and the other pole negatively. In the fifth category, students' descriptions for the magnetic field as regards the interactions are similar to that contained in school textbooks. For all that, children who use this sort of reasoning, give explanations in a microscopic level by using either the concept of elementary magnets, or the concept of cyclical micro-currents.

In the current research we attempt to study the mental representations of students 14-15 years old, with respect to the conceptualization of the magnetic field.

2. Methodology

2.1. Sample

One hundred and sixteen students (57 boys and 59 girls) 14-15 years of age coming from 6 different school classes, took part in this study. The students were in the ninth grade of school (third grade of the secondary school). It should be noted that students in Greece are taught topics related to magnetic field during the primary education as well as in the second and third year of secondary school. 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.

2.2. Design

The study of students' representations carried out through directive individual interviews and took place in laboratory classrooms at schools. 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 subsequent 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.

3. 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.

3.1. 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 the figure (Figure) and we give them the following clarifications. "In the identical trolleys A and B there is a piece of iron (F) and a magnet (A) which have the same mass. The two trolleys are strong joined with a wooden stick (P), 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".

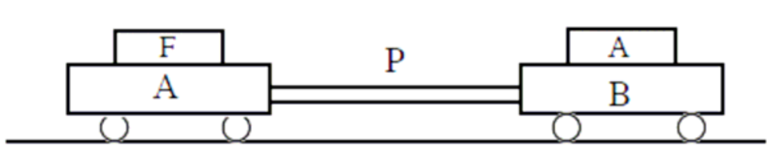

Figure 1. *Schematic representation of the Task 2*

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.

3.2. 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, "In order to find out if the magnet will always attract it … we have to investigate if it will get over the friction…. namely, we have to compare the magnet's attraction with the exerted force by the magnetic field" (Subject 102).

(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, "At the moment you put the nail very 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 surely this is not the point that you had put the nail" (S. 37).

(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 object is too heavy and as a result at this distance the magnet can not pull it" (S. 61).

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

	Frequencies	Percentages
(a) Take into account all the exerted forces	11	9,5
(b) Mention the magnetic field	74	63,8
(c) Consider the weight of the object or/and the distance from the magnet	31	26,7

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 but also the iron body will pull the magnet and as a result the trolleys will be moved … and they will crash about in the middle… (R. Why?)… Because of action and reaction" (S. 28).

(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. The dialogue below is typical. Student 64: The magnet will pull the iron body which is carried by the trolley … but also it [the magnet] will be moved towards the body … I am not sure … but since the stick is removed the trolley which carries the magnet will be also moved, a bit. Researcher: Why? For what reason? S64: By inertia? R: Why the trolley with the iron body is moved? S64: Because the magnet pulls it. R: The trolley with the magnet? S.64: I can not explain that, but I think it will be moved. R: To where? S.64: Towards the other trolley.

(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 consequently, the trolley which carries it, will roll… (R. Will the magnet be moved?) … No the magnet, because there is nothing to pull the magnet” (S. 100).

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

	Frequencies	Percentages
(a) Forces of interaction	12	10,3
(b) Motion of the vehicles with no explanation	8	6,9
(c) Exerting of a force and motion of the iron object	96	82,8

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) Quite a few children formulate types of reasoning in which they explicitly argue that the existence of the air is not connected with the magnetic interactions. For example, “The magnets will remain together independently of the air… the air does not have any relation with the magnetic force… it [the air] does not affect anything (S.26).

(b) On the contrary, some children assert 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… they will be oscillated and then they will overhang (S.66), “If there is no air to be left they will no longer be attracted… because I believe that the magnetism is carried through the air… that means the air helps” (S.70).

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

	Frequencies	Percentages
(a) The magnetic forces do not depend on the air	43	37
(b) The magnetic forces depend on the air	66	56,9
(c) Unable to formulate a certain answer	7	6,1

4. Discussion

Considering 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. This occurs since they were asked to use its properties in order to estimate real or hypothetical experimental situations. Except the task related to the propagation of the magnetic field into the air in which four (4) out of ten (10) students approximately correspond appropriately, in the rest of the tasks only one (1) out of ten

(10) students approximately can deal with the situations properly. This, of course, 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.

Indeed, 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' mental 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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