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The Discovery of Elementary Magnetic Properties in Preschool Age. Qualitative and Quantitative Research within a Piagetian Framework

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SUMMARY *This paper refers to learning situations which take place within the framework of a constructivist pedagogy. We shall present the results of research relating to the construction of elementary magnetic properties in preschool children. Five year old children, in small groups, had at their disposal different types of magnets as well as diverse objects which could be attracted by them. We formed the hypothesis that by performing various activities (playing) with them, the children on the one hand would discover the attractive force exerted on certain metallic materials and on the other would distinguish the objects which were not thus attracted. We also formed the hypothesis that the children would discover the mutual forces of interaction by manipulating the magnets. The teachers observed the activities, encouraged and questioned each child and intervened in order to help the children to coordinate their activities which were becoming more and more complex. The content analysis of the protocols gave us results which seem to confirm our hypotheses.*

RESUMÉ *Dans cet article certaines des situations d'apprentissage mises en oeuvre dans le cadre d'une pédagogie constructiviste sont étudiées. On va présenter les résultats d'une recherche qui porte sur la construction des propriétés magnétiques élémentaires chez les enfants d'âge préscolaire. Les enfants de cinq ans en petits groupes, avaient à leurs disposition de différents types d'aimants ainsi que plusieurs objets qui peuvent être attirés ou non par les aimants. Deux hypothèses ont été formulées:1) les enfants découvriront pendant les activités, la force attractive exercée sur un certain nombre de matériaux métalliques et ils distingueront les objets qui sont ou ne sont pas attirés; 2) les enfants, en manipulant les aimants, vont découvrir les forces réciproques d'interaction. Les institutrices observent les activités, encouragent, questionnent chaque enfant et interviennent pour aider les enfants à coordonner des actions de plus en plus élaborées. L'analyse du contenu des protocoles, nous offre des résultats qui semblent confirmer nos hypothèses.*

ZUSAMMENFASSUNG *In diesem Artikel handelt es sich um einigen Lernsituationen im Rahmen einer Konstruktivistischen Pädagogik. Wir führen die Ergebnisse einer Forschung auf, die sich auf der kognitiven Struktur elementarer magnetisher Fähigkeiten bei Vorschulkindern bezieht. Fünfjärigen Kindern, verteilt in kleinen Gruppen, standen Magneten verschiedener Art, so wie verschiedene Objekte zur Verfügung, die von den Magneten gezogen oder nicht gezogen werden können. Aufgrund einer gestellten Hypothese sollten die Kinder im Laufe der entsprechenden Aktivitäten die Anziehungskraft entdecken, die auf verschiedene Metallmaterialien ausgeübt wird; darüber hinaus sollten sie die Objekte jeweils unterordnen,* *ob sie gezogen oder nicht gezogen werden können. Wir haben auch die Hypothese gestellt, daß die Kinder beim Umgang mit Magneten die gegenseitigen Anziehungskräfte entdecken könnten. Die Erzieher beobachteten im Laufe des Projekts die Aktivitäten der Kinder, sie fragten sie, sie ermutigten sie und halfen ihnen bei der Koordination allmählich mehr schwieriger und komplexerer gewordenen Handlungen. Die Anhand einer Inhaltsanalyse unserer Protokolle entstandenen Ergebnisse weisen darauf hin, daß unsere Hypothesen bestädigt werden können.*

RESUMEN *Este artículo se refiere a determinadas situaciones de aprendizaje en el marco de una pedagogía constructivista. Presentamos los resultados de una investigación referida a la construcción intelectiva de las propriedades magnéticas más elementales en niños de edad preescolar. Niños de cinco años, distribuidos en pequeños grupos, han tenido a su disposición diferentes tipos de imanes, así como diversos objetos, los cuales son atraídos o no por los imanes. Durante la realización de las actividades hemos constatado la hipótesis que tenía como base el que los niños descubrirían la fuerza de atracción ejercida sobre ciertos materiales metálicos y que distinguirían los objetos que son atraídos de los que no lo son. Hemos contado también con el supuesto de que los niños, al manipular los imanes, descubrirían las fuerzas recíprocas de la interacción. Los educadores vigilan las actividades, animan y preguntan a los niños, e intervienen para ayudarlos en la coordinación de actuaciones cada vez más complejas. El análisis del contenido de nuestros registros da unos resultados que muestran la confirmación de nuestras hipótesis.*

Keywords: Magnetic properties; Constructivism; Sciences education; Preschool education.

Introduction

The activity programs of preschool education (nursery school curriculum), regardless of their orientation, almost always include activities relating to the physical sciences. The empiricist didactic trends which regard children as small adults, are mainly concerned in the effort to transmit knowledge of science, connect new experiences with the children's old experiences, and exhibit and present experiments (Chauvel & Michel, 1990). These are efforts, which are based on the questionable idea that intelligence is developed through the senses. Consequently, the observation of 'experimental' activities is considered sufficient, since the senses can impress the empirical data which can subsequently be recalled by memory whenever necessary. Other didactic proposals are based on the theoretical tradition of the social psychology of cognitive development (Doise & Mugny, 1981. Perret-Clermont, 1986) and of the teaching strategies of conceptual change (Driver, 1989) and are directed, for the time being, towards research rather than application. Therefore, if the reasoning by which children interpret physical phenomena or concepts, are in contradiction with the interpretative models of scientific theories, these efforts are directed towards the organisation of a model of teaching intervention leading to cognitive conflict, in order to facilitate the passing of thought from the spontaneous to the scientific concept (Papageorgiou, Vaitsi, Ravanis & Bagakis, 1993).

Piaget's theory of constructivism offers a framework for the development of educational theories. These theories are based on the acceptance of the crucial role played in the development of intelligence by the interaction of children with the material world surrounding them (Henriques-Christofidès, 1984). This article refers to some teaching circumstances based on the perspective of a constructivist education. That means, that we are going to present the results of a research project directed at the understanding of some basic magnetic properties by preschool children. The chief object of this study is to investigate the development of the mental constitution and representation of elementary concepts and phenomena of the physical world in an educational environment which allows the development of the autonomous activities of the child - the educators playing a purely supportive role. This study also investigates the influence on the above of the gender and age of the children with the object of ascertaining differences in their performances.

The Theoretical Framework

As we know, a basic point of Piaget's epistemology is that the development of human intelligence is the result of the constitution of intellectual structures through the activity of the subject on the objects of the material world and not of the shapeless, sensory perception of data of the physical and social environment (Piaget, 1970). It is, therefore, natural that didactic approaches based on Piaget's theory should lead to strategies which provide children with the possibility of manipulating material objects and experimenting, that is the possibility of intellectual activity capable of leading to the assimilation of physical knowledge. In particular, with respect to the constitution of physical knowledge, the educational procedures suggested for preschool children have the characteristics mentioned above. These are procedures at the centre of which is situated the free but carefully supported initiative of the children, with the nursery-school teachers playing a particular, encouraging and analysing part in the activities.

Kamii (1982) and Kamii-De Vries (1978) express the opinion that at the pre-school age we should juxtapose the "activities of physical knowledge" and the "teaching of science". The teaching of physics focuses on the object to be taught, the laws of physics, scientific terminology and research methodology. On the contrary, the activities of physical knowledge focus on the progress of the child's activities and its discoveries. Kamii (1982, p.14-29) and Kamii-De Vries (1977, p. 410) suggests a frame of educational principles based on Piaget's theory. In this context they suggest the development of acts corresponding to the different phases of the evolution of the activity as follows :

1) The preparation of the activity and the formation of questions according to the kind of action on the object.

2) The introduction of an activity in a way which maximises the initiative of the child.

3) Starting with games not requiring any kind of social cooperation. Providing every child with its own material so that individual work with it can in principle be effected.

4) Comprehension of what the child thinks and reaction of nursery-school teachers accordingly.

5) Encouragement of interaction between the children.

6) Choice of activity which takes into account the general intellectual development of the child.

7) Encouraging the child to think about its own activities.

Crahay and Delhaxhe (1988, p. 9-13), while studying, within the same theoretical framework, the free activity of nursery-school children in an environment rich in educational material, observed that the approach to the objects of the physical world is always achieved in a constant order by the children. Children set goals on the basis of which they organize activities and come to some results. These goals were either set at the beginning or during the haphazard use of the objects. Thus, educational planning suggests a series of actions which include the following phases:

1) Predictions of the nursery-school teacher prior to the activity.

At first, the nursery-school teachers are responsible for the choice of the field of activities. They are, therefore, also responsible for determining the character, the quality and the quantity of the material which will be used, as well as the classrooms required or their arrangement. The didactic objects chosen should offer the opportunity of experimental interaction with specific material and should not be taken at random from daily life. As soon as the teacher chooses the objects and the material, he/she should attempt some predictions about the level of the quality of the children's activity or the possibility of their showing initiative, so as to be in a position to encourage their own plans, help them transcend any failures and propose new activities. That is, he/she should formulate a predictive plan for each child on the basis of which he/she will observe the whole process.

2) During the activity

The nursery-school teachers present the working material to the children (e.g. magnets, springs, etc.) without showing them how to use it. As soon as the children become familiarized with these materials, they start organising simple patterns, that is, small constructions, representations of objects, etc. At this phase the nursery-school teacher notices and observes the activities of the children and records in as objective a way as possible their activities, difficulties and failures. The teacher asks them about their goals and encourages them if they succeed in achieving a desired result. When the teacher finds out that they fail in achieving their goals or when the teacher judges that intervention by the adults is necessary in order to set more complex goals, he/she intervenes based on the plans he/she had predicted or as required by an unexpected development. Whenever the children complete a pattern, they often ask to repeat the same activity in spite of their success the first time. They are very likely motivated by the satisfaction achieved by this success and the encouragement and appreciation of the teacher. From the didactic point of view the repetition of these activities is also most important, because the order of the activities demands a coordination of a number of particular acts, which should not be considered as achieved despite the fact that the child has attained the desired goal. It quite often happens that children fail when they try to repeat the same activity. The repetition of activities stabilises cognitive coordination and prepares the thought of the child for the achievement of further such coordination.

3) Analysis after the activity

The teacher, having collected observations of the children's activities, with or without his/her intervention, may then analyse, for each child or groups of children, these observations, trying to answer questions like "How did they act?", "Which actions did they perform?", "Which are the most important difficulties which they encounter?". As soon as the teacher analyses the free activities, he/she should locate the results of his/her own attitude, whether this consists of encouragement or questioning or of specific intervention. This analysis is facilitated if the teacher attempts to answer questions of the following sort: "Did the child change its manner of reacting?", "Did it take any initiative?", Did the child meet some insuperable difficulties?", "Was the child led to any new actions?". This analysis obviously leads to exact findings as far as the possibilities of the children are concerned and allows the teacher to repeat and expand the activities which in any case cannot be developed at one go. In addition, the teachers have the opportunity of evaluating their own actions, but also of locating the students which present the greatest difficulties, as well as the kind of difficulties concerned, and of directing accordingly his/her interventions, so that the children be led to successful activities, both as regards the results of their actions as well as regards their intellectual formation.

It is obvious, that the strategies of Kamii-De Vries and Crahay-Delhaxhe move in the same direction, since, by accepting Piaget's theory, they plan their activities around the autonomous interaction of the child with the material world. On the basis of the above strategies, we tried to research the success of an effort to organise activities of children with magnets, the aim being their understanding of the properties of magnets. We chose magnetic materials because they present peculiarities in relation to common materials and as a result create an environment which might turn out to be significant since it might become a source of new experiences for preschool children. In fact, the attractive forces exerted at a distance by magnets on some nonmagnetic materials, the mutual attractive or repulsive interactions without contact, could appear magical to the child. The relevant research showed that up to the age of seven as children discover magnetic forces 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 (Piaget & Chollet, 1973). 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 (Vamvakoussis, 1984). A lot of researchers, though, support the positive influence of children's free activities with magnetic materials for the discovery of elementary magnetic properties (Hildebrand, 1981. Crahay & Delhaxhe, 1988a. Chauvel & Michel, 1990).

This is exactly what we attempted to do in our research project. The hypotheses we formulated were that during the activity the children :

1) will discover the attractive forces exerted by magnets on certain materials,

2) will distinguish materials susceptible to magnetic forces from materials not susceptible to such forces,

3) will discover the mutual attractive and repulsive action of magnets.

With respect to all three hypotheses our research also included the influence of the children's gender and age.

As regards gender, in the relevant literature we encounter differences between boys and girls in studies which attempt to measure the performance or the attitudes of children with the respect to the physical sciences (IEA, 1988). However, studies, which show that boys perform better than girls, on the one hand refer to older children, while on the other they measure what the children learn in the context of the traditional school system. Given that we refer to children of preschool age and that we do not attempt to evaluate the acquisition of school knowledge, but the possibility of constructing and representing some aspects of a physical phenomenon, we may express some reservations and questions concerning the possible differences expected.

As regards the children's age, significant differences are expected. In so far as the developmental level of thought is concerned, in Piagetian terms all subjects are at the phase of pre-operational thinking. The older children, however, have developed representational abilities and better psycho-motor coordination, while they are usually better-adapted to nursery-school conditions. It is, thus, natural, both from a psycho-cognitive as well as from an educational perspective, that they should perform better than younger children.

Method

Subjects

Seventy-nine individuals, attending nursery-schools in Patras located in regions with the same social characteristics, participated in the research process. The children's parents had no special education in science. As to gender, the sample contained 40 girls and 39 boys. The average age of the boys was 5 years and 4 months (S.D. 5.75 months), while the average age of the girls was 5 years and 3 months (S.D. 5.20). As to age, the sample was divided into two groups. The first group consisted of 38 children with an average age of 4 years and 10 months (S.D. 2.21 months), while the second group consisted of 41 children with an average age of 5 years and 8 months (S.D. 2.14 months). The selection of the subjects was done by stratification random sampling (draw) from amongst those who had agreed to 'play' with us. Of course the problems relating to the voluntary participation of subjects are well-known (Rosenthal & Rosnow, 1969). The individuals which volunteer to participate in experiments usually occupy high professional positions, are highly intelligent, are not authoritarian and are generally well-adapted to their environment. In the case of our research, however, some of the above factors, such as professional status, are obviously irrelevant, while the remaining factors do not seem to exert any significant influence given that they refer to adults and not to situations in which the subjects are five-year old children which are simply willing to play with the nursery school teachers. Of course even in our case voluntary participation may have concrete causes, such as the facility to familiarize themselves with adults, being interested or in the mood to participate in activities other than the usual classroom ones, factors which depend on other variables. This problem, however, by far transcends the limits of this study.

The children worked in three-member and four-member groups. In their classes they did not participate in activities with magnets until the moment of the research process.

The Process

After having selected the children and formed them into groups, we explained to them precisely the 'game' we were to play. We gave each group of children a number of disk-like and rod-like magnets, as well as materials some of which are attracted by magnets and some not (little metallic rods, clips, drawing pins, plastic pen caps, small pieces of paper, etc.). These materials were presented one by one by a nursery school teacher at the beginning of the process and handed over to the children for familiarisation. The teacher then asked the children to take the materials on the table and play with them. The children take the initiative and effect various constructions (small aeroplanes, bridges, etc.) which they characterise as such either on their own initiative or in answer to the teacher's questions. Whenever the children fail at their constructions, the teachers intervene in order to help them execute their plans. Certain subjects, lacking good psycho-motor coordination, are not able to manipulate the materials as they wish, with the result that they encounter practical obstacles which they, at times, cannot overcome by themselves.

The teachers also attempted to intervene when the children abandoned their occupation or when they started to play by using the rest of the material without the magnets. Interaction between children was desired, so we allowed and encouraged it. That is, we let the children observe the work of other children and we urged them to cooperate in the creation of a common construction and the exchange of the material they selected. Each group worked for approximately 20 minutes. The whole procedure did not take place in a classroom but in a specially arranged 'laboratory' in the nursery-school. This 'laboratory' was a small room usually used as an office by the teachers. In this room there were no factors, such as objects, apparatus and the presence of persons not involved in the relevant 'experimental' procedure, which would disturb the subjects' activities. For purposes of the research the room was arranged in a specific manner; the children belonging to a group all worked at the same table with a teacher. The researcher was in the room in a position from which he could observe the activity without disturbing it.

The efforts of the first four groups (twelve subjects) were recorded and the video-tapes analysed. From this analysis we arrived at an observation protocol on the basis of which we recorded the activities of the remaining 67 subjects which participated in the 'experimental' procedure. The activities of each group of children were recorded by a researcher on the basis of natural observation. The same researcher analysed all the relevant protocols. This procedure was followed for all 79 of the subjects.

Results

The analysis of the results has a quantitative and qualitative character. We attempted to examine not only the frequency of a specific achievement, but also the development of the activity, as well as recording and analysing the circumstances in which it took place. The axes on the basis of which we recorded our comments are the following:

a) Random discoveries by the children.
b) Execution of activities based on the children's constructions.
c) New patterns after the discovery of magnetic properties.
d) Completion of constructions with the help of the nursery-school teachers.
e) Resumption of initiatives after the intervention of the teachers.

We considered that our hypotheses were confirmed if the children themselves, in cooperation amongst themselves or with the intervention of the teacher, succeeded in discovering magnetic attraction, in distinguishing between magnetic and non-magnet materials and in locating the mutual attractive and repulsive forces between the magnets.

1. Discovery of the attractive properties of the magnets on nonmagnetic material.

At first 55 out of 79 children accidentally discovered the attractive magnetic property. That is, using a magnet they accidentally attracted a metal object. Usually they placed it in a position where the magnet attracted it. After experimenting a few times and failing to detach it definitively from the magnet, they discovered that they had to remove it to a much longer distance. It is interesting here to note the surprise of the children when they discovered this property. For example, Laura, a girl, after she finding out to her surprise that the magnet 'sticks', she touches the end of the magnet and looks at her hand, while immediately afterward she checks to see if the magnet 'sticks' to her face. In this case Laura attributes magnetic attraction to some kind of 'glue' which she tries to find by touch. As Peter accidentally moves a bar magnet it attracts some drawing pins. Looking at the end of the magnet, he says: "We have a lot of glue here ... our hands will get stuck". 12 of the rest of the children did not take any initiative; either because they hesitated or because the material did not suffice as the children who were playing had used it up. But they were very impressed, they carefully observed the activities and we can conclude that they understood exactly what was happening, as later while they were playing, they only made slight attempts to confirm the predictions they seemed to be making, while afterwards they worked with or easily used the attractive properties of magnets by organising and applying constructions on the basis of this property. For example, Mary, one of the younger girls, after observing the activities of the other children for about ten minutes without herself being active at all, took a rod-shaped magnet, chose only objects attracted by it and, having placed them at one end of the magnet, in answer to a relevant question by the teacher said that she had made a snake with its tail.

The last 12 children did not seem to be able to recognise the attractive properties of the magnets. They used the magnets and the other materials without differentiating between them, while in their constructions they did not utilise the attractive properties of the magnets in spite of the interventions of the teachers who attempted to lead the children towards this discovery.

Concerning gender, as appears in Table I, we did not find any statistically significant difference between boys and girls. In fact 32 boys and 35 girls were successful, while 7 boys and 5 girls failed ($X^2 = 0.455$, $p > 0.1$). On the contrary, in the group of younger children there were 9 subjects out of the 38 who did not discover the magnetic properties compared to 3 subjects out of the 41 of the group of the older children. With respect to age, then, we discovered a small superiority of the older children compared to the younger ones ($X^2 = 4.101$, $p < 0.05$. Table I).

TABLE I. Frequencies of subjects discovering the attractive magnetic properties

	Boys	Girls	
Younger children	15	14	29
Older children	17	21	38
	32	35	

2. *Differentiation between magnetic and nonmagnetic materials*

After the children discover the attractive properties of the magnets, they start attracting various objects - usually the objects which happen to be near them. They, thus, make various attempts in this direction. In this way they have the chance to discover that the drawing pins or clips are attracted by the magnet, while a plastic box, e.g., is not attracted in spite of repeated efforts. This process of recognition is repeated several times and it obviously has the character of trials. Immediately afterwards or at the same time, the children conceive some patterns and try to execute them. In reality, this constitutes the main phase of the activity. The children start to use the whole material in their attempt to promote their plans. For example, by supporting a metallic bar vertically to the one pole of the bar magnet, they form an 'axe', by placing drawing pins on the end of a bar magnet, they form a 'ventilator', or by using clips they make a 'light'. In the course of time the patterns multiply and we now have a set of several diverse activities with the same materials : 'streets', 'knives', 'shops', 'tables', as well as a number of undefined forms. It is important to note, that the more the number of patterns grows the more the children choose magnetic materials, that is, they gradually abandon the nonmagnetic materials. We also observed that certain children, motivated by the novel behaviour they had discovered in their materials, showed a strong interest in using objects capable of being magnetically attracted, even when they had no specific plan of action. Alexander, for instance, made a big construction out of such objects. When the teacher asked him to explain what it was that he had made, after thinking a little, he answered: "I don't know. But it is beautiful".

In addition, the more complex the patterns become, the more chances they have for cooperation. Thus, whenever some children get tired and abandon their efforts, but go on watching the activities of the other children, they intervene by giving advice and making corrections. In a number of cases the teachers have the opportunity to become involved in the process. For example, Sotiris builds a 'bridge' by placing two small metallic bars in an upright position and supporting a magnet on their ends. When he tries to put supports at the foot of the bridge, he uses matches which do not 'stick', as he discovers after a few failed attempts. The teacher then urges Sotiris to use clips so as to complete the task he has planned. In another case, Laura puts a few drawing pins pinned to small pieces of paper in a box and pulls them out of the box with a magnet. The teacher urges her to repeat this activity using only the pieces of paper, thus leading Laura to failure and to the distinction between material capable of being attracted and material not so capable.

After a sufficient number of activities, it became obvious that many children distinguish the materials capable of being attracted by magnets since they select them and use them without any particular difficulty. In fact, after the end of this experimental process 32 boys and 30 girls succeed in achieving this distinction, while the remaining 7 boys and 10 girls have difficulties, since they try to use wooden or plastic materials as a magnets (Table II). So, while there is no statistically significant difference as to gender ($X^2 = 0.58$, $p > 0.1$), as to age the difference is great since the twelve children who do not distinguish magnetic from nonmagnetic materials belong to the group of younger children of which 26 do succeed in distinguishing between the two. From the group of older children 36 are successful, while 5 fail ($X^2 = 4.387$, $p < 0.05$. Table II).

TABLE II. Frequencies of subjects distinguishing magnetic and non-magnetic materials

	Boys	Girls	
Younger children	12	14	26
Older children	20	16	36
	32	30	

3. *The discovery of mutual attractive and repulsive forces of the magnets*

While some children are using two magnets they discover that the magnets 'stick' together. They are not particularly impressed by this fact since they already know the attractive property. But when two ends of magnets accidentally come into contact with the same magnetic pole and are repulsed, the children are impressed. At first they in fact insist on 'sticking' together the two poles which are repulsed. Vassilis, for example, after trying in every possible way to join two cylindrical magnets which repulse each other, seems to give up this idea. Accidentally, however, as one magnet turns in his hand, he achieves his goal. That is, he succeeds at the same time in distinguishing between attraction and repulsion, because when he later attempts to repeat his original plan, he at once rotates the magnet in order to change the pole as soon as he perceives the repulsion. Peter from the very beginning used two rod-like magnets and discovered their mutual repulsion by chance. Because he was surprised by this kind of interaction he repeated the same activity a number of times. Afterwards, after laying down the magnet he was holding in his right hand, he began to bring various objects close to the magnet in his left hand trying to recapture the phenomenon of repulsion. He attempted this at first with various metallic objects, although he already knew that these were attracted to the magnet; however, he very soon gave up such attempts. He then used various plastic and wooden objects - naturally with no success. Finally he used a cylindrical magnet and once more observed the phenomenon of mutual repulsion. "Only this can [do it]" he said and went on playing with the two magnets.

After the initial discovery of repulsion, 65 children out of 79 organise plans in which we observe the use both of the attraction as well as the repulsion of the magnetic poles. The children's interest is so intense that none of their plans is abandoned and the teachers do not need to intervene. We, thus, observed children constructing 'trains' with 'wagons' of magnets attracting each other, 'police' hunting 'thieves' using the repulsive powers of magnets or 'dancing' magnets. The rest of the children who did not try to work with two magnets, carefully observed with great interest the relevant activities of other children. The teachers tried to urge these children to work with two magnets, but in the case in which they used two or more magnets, they still could not distinguish the attractive from the repulsive forces. Therefore, we cannot claim that they discovered repulsion. In the case of our third hypothesis we found no differences between the performance of boys and girls, seeing that 33 out of 39 boys and 32 out of 40 girls were successful ($X^2 = 0.288$, $p > 0.1$. Table III). In so far as age is concerned we observe a statistically significant difference in favour of the older children, since of the older children 38 were successful and 3 failed, while of the younger children 27 were successful and 11 failed ($X^2 = 6.328$, $p < 0.02$. Table III).

TABLE III. Frequencies of subjects discovering of mutually attracting and repulsing forces between magnets

	Boys	Girls	
Younger children	14	13	27
Older children	19	19	38
	33	32	

Discussion

The results of the research process allow us to claim that our hypotheses were confirmed. The majority of children discover the action of attractive magnetic forces on nonmagnetic materials and the attractive and repulsive forces between magnets, as well as distinguishing magnetic and nonmagnetic materials. As we can see from our data, gender does not seem to play any significant part in the discovery of elementary magnetic properties. However, the age of the children, up to a point' does present itself as an obstacle. The younger children, on the one hand do not easily take the initiative, while on the other hand a number of them do not direct their activity towards the desired goals. They keep themselves busy for a long time with only a few materials and abandon their efforts relatively easily. Piaget's theoretical framework could lead us to formulate various interpretations as to the observed differences between younger and older children. To begin with the research project was planned in such a way that the immediate interaction of the subjects with the objects would possibly lead to the constitution of physical knowledge through empirical abstraction. However, the transition from physical knowledge to representation, which would allow a systematic cognitive organisation of what was learned by the children about magnets and their properties, requires the existence of logical schemas of thought, which may possibly not have been constituted (in the case of the younger children) or may not be constituted during the process followed. For, the objectives set by us, such as the distinction between magnetic and nonmagnetic materials or the recognition of attractive and repulsive forces, require the classification of objects on the basis of their magnetic properties. This classification, however, presupposes the ability to form categories which, at the level of pre-operational thinking, is not always achieved through the functional properties of objects but through their identity or the similarities between them (Piaget 1967). It, thus, seems that the small differences in age between the subjects do influence the mental constitution of elementary magnetic properties, since the differences between their cognitive capacities may be crucial for this research project.

In addition, irrespective of whether they fail or succeed in their efforts, the children of a younger age need the help of the teachers to a greater extent. We could possibly attribute this to their lack of good psycho-motor coordination as well as to their reduced ability to concentrate compared to the older children. Moreover, it is possible that the younger subjects may not be familiar with circumstances of group activity or with activities having concrete and circumscribed goals. Nevertheless, we cannot conclude, even in the case of the younger children, that the activities failed since two thirds of them came up to the expectations of all our hypotheses. Of the older children 9 out of 10 satisfactorily corroborated the hypotheses of our research project, since they succeeded more or less equally in all three goals we set. As our results show both in the case of the older children as well as in the case of the younger ones, most difficulties are encountered in distinguishing materials susceptible to magnetic forces from materials not susceptible to such forces. As regards this matter a specific didactic intervention would, thus, seem to be called for.

In so far as the part played by the teachers is concerned, this seems to be of significance for the whole duration of the children's activities. Because, not only do they organise the educational environment, but they also systematically follow the activities of the children, intervening precisely at the points where these require support in order to complete their plans or overcome obstacles of a psycho-motor kind. In this way the teachers perform with the children activities the latter are not as yet able to perform without help and which they will later be capable of successfully undertaking alone. From this point of view the educational activities of the teachers refer one to Vygotsky's idea (1985) of learning as the zone of proximal development.

Consequently, the free activity of the children with the materials, in conjunction with the appropriate support of the teachers, appears in the case of magnets to lead to the construction of the desired 'scientific' knowledge. In no way should this be taken as showing that the method should be generalised. To begin with, it is obvious that the methodology we employed could be used if the material at hand allows its manipulation by children. Concerning this matter, however, there are severe limitations, since in the physical sciences the experimental material is often hard to use or dangerous. Furthermore, from another point of view, the level of the children's intellectual constitution and the special character of didactic objects often lead us to the development of activities based on another kind of teaching strategies in which the teacher's intervention is much more active. Another problem which is raised concerns the effectiveness of the experimental procedure we presented, given that it was of an experimental character since it was realised in a special place and with small groups of children. To transfer a similar proceeding to real preschool classes, would allow us to arrive at useful conclusions. In any case, however, the organising of related activities raises interesting questions, both from an educational as well as from a research point of view, within the framework of science teaching for preschool ages in relation to the limits and range of Piagetian type teaching strategies.

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