

Teaching Magnetism to Preschool Children: The Effectiveness of Picture Story Reading

Michail Kalogiannakis¹  · Georgia-Marina Nirgianaki¹ · Stamatis Papadakis¹ 

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Abstract As the introduction of natural sciences in early childhood education differs from natural sciences for adults, planning appropriate activities for preschool is a delicate task with various dimensions and parameters. Teaching natural sciences in kindergarten can be a complex procedure which combines exploring and comprehending children's perceptions, scientific content and the learning environment. Magnetism, which is very attractive subject for young children, is a commonly negotiated topic at the preschool level. In this paper, we present an empirical case study that examines whether the picture story reading method can be beneficial for young children learning about magnetism. Findings underline the importance of drawing on a variety of evidence in assessing young children's understanding of magnets.

Keywords Early childhood education · Magnetism · Educational intervention · Kindergarten · Story reading

Introduction

Learning about magnetism is an important component of natural science education (Van Hook and Huziak-Clark 2007). Primary science education has often been more about the acquisition of conceptual knowledge (Johnston 2009), and thus planning appropriate activities for preschool constitutes a delicate task with various dimensions and parameters

(French 2004; Gerde et al. 2013). In recent years, there has been continuously increasing interest in early childhood science education (Fleer and Pramling 2014; French 2004; Greenspan 2016), as natural sciences offer a wide range of exploration and creativity to young children.

Students' understanding of magnets has been studied extensively over the past 20 years, covering a wide range of age groups, from primary to university level. An understanding of the phenomenon of magnetism at the preschool level is associated with the forces of attraction and repulsion and it is based on interaction between magnets (Constantinou et al. 2013). Although the National Research Council (NRC 1996) considers magnetism a basic concept for young children, limited research has been carried out with the youngest children in preschool education (Van Hook and Huziak-Clark 2007). Recently, the Next Generation Science Standards has moved exploration of magnetic attraction to third grade because of the abstract nature of an invisible force field (National Research Council 2012). Often, kindergarten students interact with magnetic letters on a board, refrigerator magnets, and blocks or other toys that are attached by magnets. Additionally, preschoolers tend to believe in "magic", so they need to know the nature of science. Even preschoolers must understand that there are things that can be explained in non-visual ways. For these reasons, we argue that the teaching of magnetism in preschool education is important, as it is indeed part of a preschooler's world.

In this article, we focus on teaching magnetism to young children. Despite the lack of relevant research, the topic of magnets was selected because it is commonly negotiated at the preschool level, as it constitutes a very attractive subject for young children. As simple as the phenomenon of magnetism seems, it is complicated for preschool children. As Barrow (2000) states, often children accidentally discover magnetic properties but have

✉ Michail Kalogiannakis
mkalogian@edc.uoc.gr
<http://crete.academia.edu/MichailKalogiannakis>
https://www.researchgate.net/profile/Michail_Kalogiannakis

¹ Department of Preschool Education, Faculty of Education, University of Crete, University Campus - Gallos, 74100 Rethymno, Crete, Greece

difficulties in separating the objects that are attracted to a magnet. Children tend to believe that all objects have their own magnetic properties and that these properties exist regardless of objects' interactions with other entities. When children think about magnets, they tend to believe that they are objects that can simply pull other objects. Most of them also believe that the power of magnets depends on their size, and that magnets pull both metal and silver objects. Most young children think that magnetic fields are created only by magnets (Barrow 2000). The present study built on these findings and seeks to investigate the effectiveness of a teaching intervention based on pictured story reading on the development of children's perceptions of magnetism.

Magnetism Literature Review and Teaching Interventions

Magnetism and Magnets

Naturally occurring magnets are composed of the mineral magnetite, which is a dense iron oxide, often called lodestone (Jiles 1990). The word "magnetism" derives from the ancient Greek word *Magnesia*, an area where ancient Greeks first found, almost 2000 years ago, a very special kind of rock that had the ability to attract pieces of iron. They called this rock *magnitis*. The Chinese first used *magnitis* in the twelfth century, making compasses for their voyages. It is only in the last two centuries that we have come to a deeper understanding of magnetism. Jiles (1990) refers to the following fundamental elements of a magnet:

- A magnet has two different sides called poles, one of which is called the north pole, while the other is called the south pole.
- The north pole of one magnet attracts the south pole of another magnet, while the north pole of one magnet repels the other magnet's north pole.
- A magnet forms an invisible area of magnetism, called a magnetic field.
- The north pole of a magnet points roughly toward the Earth's North Pole and vice-versa.
- Break a magnet in half and you get two smaller magnets, both with north and south poles.
- A magnet attracts iron and other paramagnetic metals, such as nickel.
- The more you run a magnet over a tool, the stronger the magnetic field created by the tool will be. This is called magnetization.

Teaching Magnetism: A Review of the Relevant Literature

In recent years, there has been growing attention to children's learning in the early years of schooling, and science in particular has become more fully established as part of the early curriculum (Glauert 2009; Papadakis et al. 2017). In the early years of their lives children begin to perceive concepts in the environment they live in, seem to be involved in learning procedures and gain greater awareness of their world (Bransford et al. 1999). Children have a predisposition to learning, and especially so in a discipline such as the natural sciences. Several studies have revealed that young children recognize similarities and sequences in their observations and have causal thinking which is limited because of their limited conceptual knowledge (Duschl et al. 2007; Johnston 2009; Ravanis 2004).

From an early age, children play with magnets without making systematic observations. Young children tend to perform spontaneous operations, which they have never conceptually classified or organized (Ravanis 1994). Piaget and Chollet (1973) found out that most children under seven years of age, as they discovered the magnetic properties of a material, attributed the attraction to the internal property of "gluing", and the repulsion to "blowing". Several studies show that young children notice the phenomenon of magnetic attraction, but are not able to provide spontaneously a clear definition of it (Barrow 2000; Christidou et al. 2009; Constantinou et al. 2013; Selman et al. 1982).

Studies show that children tend to adopt two levels of thinking about magnetic attraction. In the first level, children simply connect different events, while in the second level, children claim that an invisible force allows magnets to "pull objects" (Selman et al. 1982). Similarly, various studies have found that most children under the age of seven cannot distinguish objects/materials attracted by magnets from those that are not; they have difficulties in explaining magnetic attraction (Finley 1986; Ravanis 1994). This leads them to speculate that glue possibly exists behind the magnet, or that magnets have a mysterious, almost magical force (Finley 1986; Harlan and Rivkin 2000; Ravanis 1994). Ravanis (1994) also argued that preschool children discover the mutual forces of interaction by playing with and manipulating the magnets. Van Hook and Huziak-Clark (2007) considered that young children have adopted a bipolar model and are capable of using it to describe the interaction between magnets. That means that, from a young age, children recognize that magnets have two poles and can have distinct interactions with other magnets and materials.

Christidou et al. (2009) argue that children understand the attracting capacities of magnets and recognize that a criterion is the ability to "pull" an object from a magnet. The construction and reconstruction of a conceptual map before

and after instructional activities helped children initially to express their views, then helped develop their perceptions and finally motivated them to study magnetism (Christidou et al. 2009). For Poimenidou and Christidou (2010) there may be some positive learning outcomes when both experiential perceptions and appropriate teaching techniques are used, such as experiments, dramatic play and storytelling. Systematic planning is essential if one desires to create a framework of analysis to compare communication practices and their role in the construction of meaning in kindergarten activities about magnets and magnetic traction (Poimenidou and Christidou 2010).

An experimental study recruited 165 children aged 4–6 in an extended structured intervention in which they were guided to construct two operational definitions of a magnet (Constantinou et al. 2013). The definitions differ in the cognitive demands required of the two groups of children. In this study, Constantinou et al. (2013) found that, even though children across all ages could not initially categorize magnets, the appropriate teaching intervention led them to construct their first operational definition. For Constantinou et al. (2013) children's chronological age, not their cognitive maturation, was the most decisive factor to explain the patterns of performance in the proposed tasks.

The results from all these studies suggest that preschoolers should be given the opportunity to test and sort different items that are and are not attracted to magnets such as cardboard, plastic, and metal items (some should be iron or steel, but others should be materials such as aluminium). In this way, children will learn that many materials are not attracted to magnets; those attracted to magnets are all metals, but not all metals are attracted to magnets.

Story Reading and Teaching Magnetism in Early Childhood

The value of the opportunities to play and explore in early childhood education—the potential to create concepts, question things, and develop an initial sense of phenomena—could be more widely appreciated. Learning about magnetism can be accomplished by adding new knowledge to pre-existing knowledge, creating new concepts or rebuilding preconceived perceptions. In any case, developing children's creativity requires time and opportunities to allow them to construct a scientific comprehension of the world. Science activities have been described as supporting language and literacy skills through opportunities to learn and apply new words (Brenneman and Louro 2008). Children's creativity in the beginning of their education is very important. It is essential, therefore, that activities in preschool education define the nature of problems and formulate solutions by exploring and playing cooperatively (Ampartzaki and

Kalogiannakis 2016; Burnard et al. 2006; Craft et al. 2012; Papadakis et al. 2017; Thulin and Redfors 2017).

In preschool education, the introduction of story reading may contribute positively to the educational process (Isbell et al. 2004; Sulzby 1985; Tafa and Manolitsis 2008). Many research studies have shown that children make significant gains in various areas of development through shared storybook experiences (Isbell et al. 2004). For instance, stories can be used to enrich children's content-specific vocabulary and provide authentic opportunities for reviewing words, letters, and sounds. For Sulzby (1985) children's early development includes a shift from simply responding to pictures toward understanding stories. Reading quality children's books can enhance children's imaginations, as well as encourage them to create mental pictures (Aina 1999).

A study by Kelemen et al. (2014) showed that story reading helps children increase their factual and theoretical understanding. Additionally, story reading supports connections between science and children's everyday lives and promotes the construction of views that are consistent with the practice of science (Mantzicopoulos and Patrick 2011). Mutonyi (2016) argues that cultural tools (stories, proverbs, anecdotes) can be used to scaffold students' learning of scientific concepts. Reading quality children's books can enhance children's imaginations, as well as encourage them to create mental pictures (Aina 1999). Picture books have been proved to be an excellent tool to teach science to English language learners in primary education, as well as to encourage and enhance pupils' communication skills (Gálvez Santos and Dooly 2016).

For Isbell et al. (2004) the inclusion of storytelling assists children in expanding story comprehension and recognizing the elements of a story. With story reading children perceive that we don't read the picture, but we read the letters and that every text has something different to say (Isbell et al. 2004). We can understand the developmental process of children in language through story reading. Storytelling and story reading are both beneficial to the development of oral language complexity and comprehension in young children (Isbell et al. 2004). For a correct application of the story reading approach, Ezell and Justice (2005) argued that the way in which adults use their voice while reading a story aloud can have a big impact on attentiveness and overall enjoyment of the story itself.

The Experimental Study

Based on the above literature review, the following research questions guided the development of the interview protocol and our teaching intervention about magnets to young children:

- (a) Can drawing be a useful way to interpret children's perceptions of magnetism?
- (b) Is storytelling (i.e. using the story as a means of communication) an effective method for teaching magnetic attraction and repulsion?

Children Participants

Two kindergarten classrooms in two suburban public Greek schools were the focus of this study. The research sample consisted of 30 kindergarten children (19 boys and 11 girls) in the 2015–2016 school year. The sample ranged in age from 3 years and 11 months to 5 years and 6 months (sample mean 4 years and 8 months and standard deviation 7 months). The majority of cases were of a middle socioeconomic status. The sample was homogeneous in terms of demographics such as ethnicity and language. The research protocol conforms to the ethical guidelines of the European Union and was approved by the Institutional Review Board (IRB) of the University of Crete. Permission was given by parents and teachers prior to the research. Ethical considerations and guidelines concerning the privacy of individuals were carefully taken into account throughout the whole research process.

Research Design

The research was divided into three phases. The pre-experimental control phase, during which the measurement of the dependent variable was performed (children's prior knowledge about magnets). Through individual interviews and drawings, we asked the children questions about the definition of magnets and magnets' interactions with various objects, in conjunction with their shape and colour. We paid especially close attention to the property of attraction and repulsion. The second phase, during which the manipulation of the independent variable took place, included the storytelling approach of an illustrated fairy-tale entitled "*The opposite poles are attracted*", written by the researchers. Five 45-min lessons were taught by one of the researchers to the two kindergarten classes in the middle of the spring semester 2015–2016. In the third phase, (post-experimental), the children were asked exactly the same questions and did the same activities as in the first phase. The research design is shown in Fig. 1.

Data Collection

Data were collected at baseline and after the intervention using two different tools. The approach to data collection was designed to provide children with a range of different opportunities to show what they knew and could do (Glauert 2009). The first tool was an interview questionnaire. With

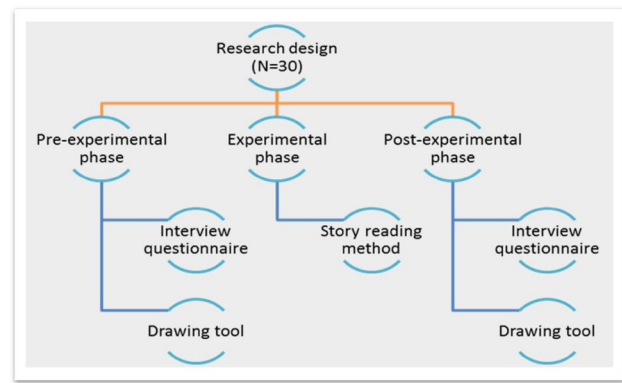


Fig. 1 The research design

the interview, researchers could meet face to face with the children to gain an overall sense of their prior knowledge of magnetism (Finley 1986; Van Hook and Huziak-Clark 2007), whereas a simple questionnaire was considered to be more impersonal. The development of the questionnaire was based on prior literature review. The questionnaire was tested in four pilot interviews with children who were not included in the final sample and minor revisions were made to clarify some of the questions. All the interviews were performed by the same researcher during the activity period. Interviews were audio-recorded and field notes made after the kindergarten teachers and the children's parents had given their permission. Care was taken to include details of children's actions that might be helpful in interpreting their responses. The duration of each interview was about twenty minutes for each child.

For the pre- and post-interview, each child was asked by the researcher, in an open-ended way, to choose two toys (either magnet or not) and tell her about it: "What can you tell me about your toys?" Follow-up questions were both closed, such as "Why does it stick (or not) with the other toy?", and open-ended, such as "Why do you think that happens?" Children were encouraged to offer reasons for their predictions. In the following extract the researcher is asking a five-year-old girl about two magnets and the child explains what she thought had happened:

Researcher They stick? I suppose (that) all magnets stick together?

Girl Some do not stick.

Researcher Which ones do not stick?

Girl If you put red and red they do not stick. If you put green and green they do not stick. If you put green and red they stick.

Researcher Each magnet should be a different colour?

As a second tool the researchers used children's drawings as they were considered a channel for children to express their ideas. During the pre-test and post-test interview, the researchers asked the children to draw what they thought would happen if a magnet came close to another magnet. Children were shown examples of magnets, asked to predict how they behave with other objects, and to explain why. Children's predictions, explanations, and actions were recorded on a prepared chart. The children were interviewed in this way because the concepts of attraction and repulsion are two magnetic properties that children can barely understand and clearly identify at this age (Constantinou et al. 2013). Children's responses, before and after the lessons, were compared and contrasted. Each of the researchers made thorough notes about the students' verbal comments and drawings.

The Teaching Intervention

The researchers chose an alternative method in early year science education—the story reading method—to teach the concept of magnetics. This method is not often used by educators, especially in teaching attraction and repulsion of magnetism. A very important reason story reading was chosen is that illustrated stories have been shown to help children identify concepts by informing them and having them observe. Children tend to associate themselves with the heroes of a story, linking their experiences with the content of the book, and this stimulates their interest in the subject. If questions are asked before, during and at the end of reading, educators can create an environment for discussions that help break down unwanted behaviours and create new patterns of action.

At the beginning of the study, the researchers explained the nature of the activity to the children. Prior to the story reading, the researchers encouraged the children to speak freely, showed them a “new friend”, a puppet in the shape of a horseshoe magnet (Fig. 2).

One of the researchers told children the following story: “The doll had come from a distant country and he had brought some things with him, such as magnets in different lengths, shapes and colours. Unfortunately, after losing some of these things, the doll needed the children's help to find them”. In this manner, the children were approached in a respectful way, as the researcher wanted to arouse their interest and have them express themselves more easily. Essentially, the doll played the role of children's mediator. Parts of the story book are presented in Figs. 3, 4, 5 and 6. A brief synopsis of the story is presented in the following paragraph.

Once upon a time there were two opposite worlds. The negative and the positive pole. The two poles hated each



Fig. 2 Children's “New friend”



Image caption: On the other side of the world, the king of the negative pole, the horseshoe magnet head, used to say the same things to his citizens: “Anyone who crosses the border of the positive pole will stay there for ever and ever!”.

Fig. 3 Parts of the story “The opposite poles attract each other”

other because of their kings' decisions. Both kings used to say to their citizens that if they ever went to the opposite pole, that would be their end. Thus, in both kingdoms, there was no happiness, because nobody could hug or even come close to each other. And then one day a courageous inhabitant of the negative pole, the magnet-head, decided to travel overland to the opposite pole, to find out if people there were happy. When he finally got there, he stuck to a girl made of iron, the can-girl. Although they desperately tried to find a way out, they couldn't. They were stuck to each other for many hours and tried and tried to become unstuck, but to no avail. They went to the can-girl's father, the king of the land, who told them that the reason they were stuck, and why the



Image caption: In the country of the horseshoe magnet-head, something strange was happening. The citizens of the country, the iron horseshoes, couldn't come close to each other! If a horseshoe tried to hug another, they were repulsed. The little horseshoes couldn't play together, the horseshoe mothers couldn't kiss or even hug their kids. So, they were all unhappy.

Fig. 4 Parts of the story “The opposite poles attract each other”

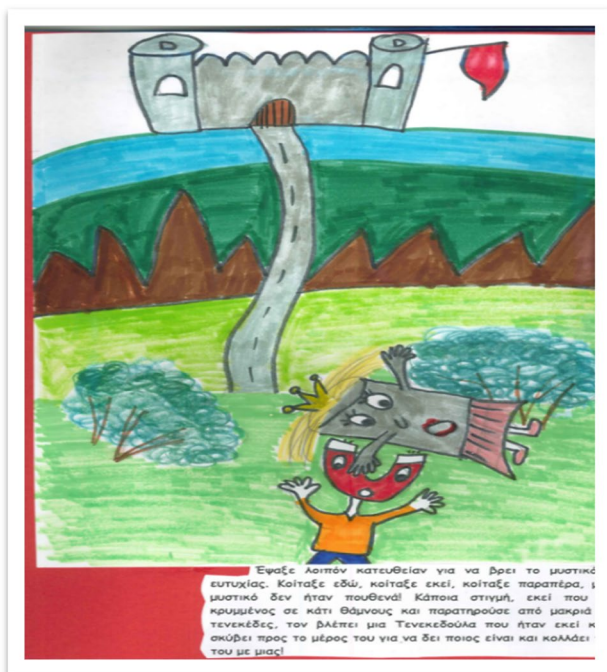


Image caption: He looked right away to find out the secret of happiness. He looked everywhere, but the secret was nowhere! Suddenly, while he was hiding behind some bushes and observing the cans, a can-girl came close to him and immediately stuck on his head!

Fig. 5 Parts of the story “The opposite poles attract each other”



Image caption: As they were tired from the journey, they sat down to rest. “You know can-girl, it is the first time in my entire life anyone ever hugged me like that,” said the magnet head. “I feel a bit strange but I like it! Do you here in the positive pole hug a lot?” “We used to” she answered.

Fig. 6 Parts of the story “The opposite poles attract each other”

inhabitants of the two lands were not allowed to meet, was that they were of opposite poles, and would naturally stick together. The inhabitants of one country repelled each other, whereas an inhabitant of the positive pole attracted and “hugged” an inhabitant of the negative pole. So, the secret of happiness was to have the citizens of the two poles meet and stick to, or hug, each other. The magnet-head prince, and the can-girl princess decided to get married so that both kingdoms could come into contact and have all citizens find happiness.

During this phase, children were also provided with a collection of small toys (toys with magnetic body parts, magnetic frogs and marbles) and a range of various other components (wood, iron, and steel products) and were left to undertake their own explorations. Pre-school children were given the opportunity to test and sort different items that are attracted or not to magnets.

Results

The Children's Drawings as a Useful Tool to Interpret Their Perceptions of Magnetism

The children's drawings prior to the intervention had several similarities. First, all the sketches had magnets that stick or

were about to stick together. Only three children claimed that some magnets do not stick together. More specifically, one child claimed that magnets do not stick together “because they are the same colour” and the other two said “because they are a different colour and different shape”. There were also similarities in the way children depicted how magnets stick together. To show that magnets stick together, many children (13 of 30) drew the magnets one on top of the other, or one opposite the other. Other children (17 of 30), in order to describe the same phenomenon, drew little lines, dashes, or arrows between the magnets, to represent either the magnet ‘glue’ or generally the invisible magnetic force.

Exploring the children’s drawings, the researchers also noticed differences in the shapes and colours that the children used. Concerning the shape of the magnets, most children (26 of 30) drew the same shape whether they were rectangular, round or horseshoe. The rest of the children (4 of 30) drew magnets of various shapes sticking together. The colours used by most of the children (18 of 30) were red and black, equally distributed. A small number of children imagined that magnets were blue/light blue (6 of 30), yellow (2 of 30), grey (3 of 30) and green (1 of 30). Some of the drawings and the comments made by the children prior to the teaching intervention are presented in Table 1.

The children’s drawings after the intervention showed several similarities and differences in relation to their drawings in the first phase; First, it should be noted that most of the drawings (22 of 30) indicated that the children had understood the fact that the magnets not only “stick together”, but also repel one another under certain conditions. Through semi-structured interviews and the analysis of children’s drawings the researchers noticed that several children (10 of 30) believed that the attraction or repulsion of magnets depended on colour: if the magnets are the same colour, they repel, if they are different colours, they stick together. Other children (6 of 30), defined the magnet’s side

as responsible for the attraction and repulsion, believing that the magnets have a right and wrong side. A small group of children (6 of 30) claimed that magnets must have different forces in order for them to stick together. They noted that negative with negative or positive with positive repel, while negative with positive stick together.

In this phase, most children (22 of 30) used in their drawings signs such as arrows, dashes or thunderbolts to represent the invisible power of the magnet that causes attraction and repulsion. The rest of the children (8 of 30) drew magnets that stuck together whether by glue, rope, or in some magical way. Some of the children’s drawings and comments after the teaching intervention, are presented in Table 2.

Effectiveness of Story Reading Methods in Preschool Children’s General Knowledge and Particularly in the Phenomenon of Attraction and Repulsion of Magnets

The results of this research question were obtained considering all the research tools: the children’s drawings, the verbal explanations and a test that the children did after the interview. In the interviews, in the first general category, children did not give adequate responses in defining magnets before the intervention. After the intervention, however, 83.3% of the sample gave adequate definitions. On the usefulness of magnets, before the intervention, only 23.3% gave a sufficient answer, while after the intervention 53.3%, i.e., more than half the sample of children, understood the usefulness of magnets. Regarding the material of magnets, in the control interview of prior knowledge only 36.7% of children managed to correctly identify the material. After the intervention an overwhelming 96.7% of children correctly identified iron the material of which magnets are made. The same is not true regarding the question of the origins of magnets, as there was no

Table 1 Children’s drawings and comments prior to the teaching intervention

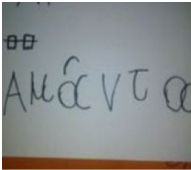
Children’s drawings	Children’s comments	Children’s drawings	Children’s comments
	<i>“I drew this big circle and this circle which are glued and this horseshoe magnet that goes near them.”</i>		<i>“I drew two magnets trying to stick each other and the brown colour between them is the glue.”</i>
	<i>“I made two black magnets linked by a small line, something like strength.”</i>		<i>“I drew magnets for you, which stick to each other. It is the line power that makes them stick.”</i>

Table 2 Children's drawings and comments after the teaching intervention

Children's drawings	Children's comments	Children's drawings	Children's comments
	"I have drawn two magnets that are the same colour and so get stuck. I also drew four magnets that stick together because they are different colours but the two browns don't stick because they are the same colour."		"The yellow colour is the invisible force that sticks magnets. The brown magnet does not stick to the other which is upside down."
	"I draw magnets that stick together because they are of a different colour and this line is their power."		"I've drawn four magnets that stick together and this small line is their magic power."

adequate answer near the scientific model, either before or after the intervention. To avoid having children simply repeat information they were told through the story without really understanding what they were saying we regularly asked them to answer in their own words and to describe 'what' and 'how' perspectives of magnetism.

Concerning the properties of magnets, before reading the story the children gave no adequate responses, while after the reading 56.7%, gave suitable answers. As far as the variables that determine attraction or repulsion of magnets, before the intervention there were no adequate answers, as almost all the children believed that magnets can only attract. After the intervention, 50% of the sample gave adequate responses. The last question was about the properties of magnets in contact with other objects. Prior to the teaching intervention only 33.3% gave the correct answer. After the intervention all the children gave the right answer. Table 3 presents the children's answers in the main axes of the interview prior to the teaching intervention.

Before the intervention 90% of children believed that all magnets stick together. After the intervention, there was a small percentage of 26.7% whose prior knowledge was not augmented and who still believed that all magnets stick together, without exception. However, 73.3%, over half the children, changed their opinion and even expressed several causes which determined attraction or repulsion. A significant proportion, 33.3%, claimed that magnets of the same colour cannot stick together, whereas different colour magnets do stick together. Before the intervention only 6.7% had maintained this approach. Furthermore, 20% maintained that magnets stick together only when they are placed on the correct side. Another 20%, said that magnets which have the same power do not stick together. Prior to the intervention, this percentage was only 3.3%.

Prior to the teaching intervention a majority of children (56.7%) believed that magnets have a glue that makes them stick together. After the intervention, only 26.7% of the children maintained this view, while the remaining 73.3%

Table 3 Children's responses in the main axes of the interview prior to the teaching intervention

	Magnet definition		Magnet usefulness		Magnet material		Magnet origin		Magnets' properties when come into contact		Variables that mediate magnets attraction or repulsion		Magnets' properties in contact with objects	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Adequate answers	–	–	7	–	11	–	–	–	–	–	–	–	10	–
Partly adequate answers	9	6	–	11	–	–	11	–	11	7	–	–	–	–
Not adequate answers	–	–	–	–	–	4	–	6	–	–	9	9	–	3

M Male, F Female

evinced, in their drawings and comments, that the reason for attraction is an invisible force. In addition, the children's drawings before the intervention had a more austere character. That is to say, they drew simple shapes that combined to portray the attraction of magnets. After the intervention, however, 53.3% of children, inspired by the story, drew magnets in a more imaginative way. They drew magnets as characters or drew fictional characters to portray the magnets. Also, children were inspired by the protagonist, (a horseshoe magnet) and as a result they drew more horseshoe magnets than other shapes. Table 4 presents the children's answers in the main axes of the interview after the teaching intervention.

As Ravanis (1994) stated, regarding 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 natural sciences. The participants were divided into two groups according to their genders. In this study, interestingly, boys were found to be more knowledgeable than girls in many aspects of magnets prior to the teaching intervention. As the data in our study did not include diagnostic interviews with parents to see if scientific ideas are more common in boys than girls, a possible explanation could be that boys have more toys with magnetic parts in their homes in comparison with girls.

As has been shown in other studies, the children generally could not detect the difference of attraction and repulsion between magnets and that magnets have these two key properties (Ravanis 1994). An analysis of children's responses indicates that both boys and girls were confused about the nature of the magnets, while girls were more inclined to believe in an 'imaginary element' than boys. More specifically, it was not clear what exactly a magnet is, they could not find what material a magnet is made of, what magnetic properties are etc. (Van Hook and Huziak-Clark 2007). In this study, more girls than boys did not know that a magnet's pole can attract the surface of another magnet, and that the opposite pole can repel the same surface. They believed that a variety of factors are responsible for this attraction, which

were determined based on materials they were familiar with in their daily lives. For example, they considered that there is a glue between the magnets, because this is the kind of material they use in their daily lives. In addition, it was not clear to them what materials cause magnetic attraction, although they had understood the fact that a magnet generally attracts objects other than magnets. Table 5 shows the answers given by the boys and girls in some of the categories and subcategories of the questionnaire interview prior to the teaching intervention.

Following the implementation of the teaching intervention both boys and girls enriched their knowledge about magnets. Despite their young age, the majority of children managed to create an adequate definition of magnets. Furthermore, they could correctly identify the material of magnets and they understood that magnets have the properties of attraction and repulsion due to their invisible power. The majority of preschoolers in this study understood the property of a magnet to attract only iron objects, but they could not identify with sufficient certainty the origin and usefulness of the magnet either before or after the intervention. Table 6 shows the answers given by the boys and girls in some of the categories and subcategories of the questionnaire interview after the teaching intervention.

Conclusions

As demonstrated by this study, children—including more girls—before the intervention could be said overall to have had little knowledge about magnets and their properties. They also had confused ideas about the definition of magnets, their usefulness, material and origin. They did not even know that a magnet had the property of not only attracting other magnets, but also repelling them. They believed that several factors were responsible for the capacity of attraction, based on their reality. For example, they considered that there was glue in the magnets because, at their age, they use this material often. In addition, they hadn't yet clarified

Table 4 Children's responses in the main axes of the interview after the teaching intervention

	Magnet definition		Magnet usefulness		Magnet material		Magnet origin		Magnets' properties when come into contact		Variables that mediate magnets attraction or repulsion		Magnets' properties in contact with objects	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F
Adequate answers	19	6	16	–	19	10	–	–	10	7	7	8	19	11
Partly adequate answers	–	–	–	7	–	–	–	–	–	–	–	–	–	–
Not adequate answers	–	–	–	–	–	–	8	9	–	–	–	–	–	–

M Male, F Female

Table 5 Boys' and girls' answers in some of the categories and subcategories of the questionnaire interview prior to the teaching intervention

General categories	Subcategories	Number of children (girls)	Number of children (boys)
Definition of magnet	It is something that sticks	6	9
	Something that sticks in the refrigerator	3	6
	Something that sticks to metal objects	1	2
	It is something that sticks on our drawings	1	2
The magnet material	Glue	4	1
	Iron	3	11
	Plastic	1	3
	From a different material	1	3
	Paper	1	1
The properties of the magnets when they come into contact with each other	The magnets stick together	7	11
	Some magnets stick together and some do not stick together	3	5
	Only those that have something on their edge stick together	1	3
Variables that mediate either attraction or repulsion of magnets	They stick together because they have glue	3	9
	The magnets that have the same colour do not stick together, while those that have a different colour, stick together	3	5
	They stick because they are magic	3	3
	They stick because they have power	–	2

Table 6 Boys' and girls' answers in some of the categories and subcategories of the questionnaire interview prior to the teaching intervention

General categories	Subcategories	Number of children (girls)	Number of children (Boys)
Definition of magnet	Something that sticks to iron objects and other magnets	2	19
	Something that sticks to iron objects	3	–
	It is something that has an invisible power that attracts the magnets and iron objects	6	–
The material of magnets	Glue	–	–
	Iron	10	19
	Plastic	1	–
	From a different material	–	–
	Paper	–	–
The properties of the magnets when they come into contact with each other	They stick together when they have different colours	7	6
	They stick on one side, but when you change the side they do not stick together	3	10
	They always stick regardless of shape or colour	1	3
Variables that mediate either attraction or repulsion of magnets	They stick together because they have glue	1	1
	The magnets with the same colour do not stick, while those that have a different colour stick together	1	–
	They stick because they are magic	1	4
	They stick because they have an (invisible) power	8	14

which materials cause magnetic attraction, despite having understood that magnets generally also attract objects other than magnets.

Despite the relatively insufficient knowledge of the children before the teaching intervention, afterwards children of both genders showed several positive changes in their views. First, they managed to create an adequate definition

of magnets. Furthermore, they could correctly identify the material of magnets. They also understood that a magnet has the property of attraction and repulsion, and that its “invisible power” is responsible for these properties. Finally, the majority of children understood the property of a magnet to attract only iron objects, but they did not

adequately identify the origin and usefulness of the magnet, neither before nor after the intervention.

Our research shows that the children's drawings allowed them to externalize their initial knowledge of the phenomenon of magnetism. At the same time, the drawings provided the researchers with abundant evidence of the development of the children's ideas thus offering them the ability to understand children's internal cognitive representations. This is in agreement with previous studies that reported that multisensory activities (e.g. writing about magnets) that reinforce the conceptual model are important for young students to internalize cognitive strategies associated with the conceptual model of magnets (Van Hook and Huziak-Clark 2007). This study confirms the findings of previous research that indicated that children who are frequently exposed to storybook reading are more likely to use complex sentences, have increased literal and inferential comprehension skills, gain greater story concept development, increase letter and symbol recognition, and develop positive attitudes about reading (Silvern 1985).

Comparisons of the children's conversations before and after the teaching intervention suggests a number of notable differences. It seems that the alternative approach of pictorial story reading in kindergarten, together with suitable questions by the teacher and attractive incentives for the children (Hugerat et al. 2005), was particularly effective in aiding understanding of magnetism, as it brought positive results and contributed to enriching children's knowledge of magnetism. The children really liked the colourful pictures, as well as the happy ending of the story. They showed great interest in what the researcher told them and provided responses to all questions—they did not just repeat what they had heard, but tried to explain magnetism in their own ways. For instance, when asked why a magnet sticks to an airplane (in the picture), they said "I know! it is because the airplane is made of iron". Furthermore, when asked "what happens and the magnets stick together?", they answered that there is a mystery force we cannot see and when the magnets come sufficiently close to each other, the magnets may stick together or may not.

Discussion—Perspectives

In recent years, primary science education has often been about the acquisition of conceptual knowledge. This has meant that perceptions and understanding of science have shifted too, from skills to more subject knowledge (Johnston 2009). From the investigation of the relevant field's literature about teaching magnetism in preschool education it is evident that magnetism can be taught in kindergarten. It is a rich and important subject area in the natural sciences because it has multiple applications in young children's daily

lives. Our research shows that the alternative approach of pictorial story reading in kindergarten, with the right questions by the teacher and attractive incentives for children (Hugerat et al. 2005), may be particularly effective in understanding magnetism. Technology motivates and engages young people. With this in mind, we are currently planning to study how to combine the benefits of mobile technology and the use of an open ended educational environment like ScratchJr to help young children develop their knowledge of magnets and the natural sciences in general by providing a stimulating environment (Papadakis et al. 2016).

Kindergarten students are capable of developing a basic understanding of magnetism if they are provided hands-on experiences and a simple conceptual model to explain these experiences (Van Hook and Huziak-Clark 2007). Teaching natural sciences in this way is effective, meaningful, interesting, contemporary, motivating and particularly amusing.

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Compliance with Ethical Standards

Conflict of interest The authors declare that they have no conflict of interest.

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