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AIR AS A CONDUCTING MEDIUM IN CHILDREN'S IDEAS ABOUT ACTION AT A DISTANCE

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Introduction

In this study the construction of children's pre-instructed ideas regarding the fundamental concepts of gravity, air and magnetic attraction is investigated. Our research deals with the question : "Do children think that magnetic attraction needs air as a conducting medium?". It is informed by the Constructivist approach to science education which started with Kelly (1971), who stated that "*Man understands himself, his surroundings and his potentialities by devising constructs to place upon them and then testing the utility of these constructs against such criteria as the successful prediction and control of events...*" Guttierrez and Ogborn (1992) suggest similarly that people invent explanations because they seek causes for effects they see in the environment. This approach supposes the existence of the learner's pre-instructed ideas. Instances of pre-instructed ideas concerning specific scientific concepts such as air, force or weight, are already noted by Piaget (1929, 1972), at the beginning of the century. Since then many researchers have delved into children's pre-instructed ideas (Pfundt and Duit, 1990; Carmichael, Watts, Driver, Holding, Phillips and Twigger, 1990). The interest of science educators in children's intuitive ideas has been significantly motivated by Ausubel's learning theory (1968) where the importance of the learner's prior knowledge in influencing his understanding of new material is stressed. Similarly, Di Sessa (1988) in his "knowledge in pieces" theory notes the relevance of children's pre-instructed ideas to the learning process. Minstrell (1992) as well as Clement(1982) also emphasize the effect of existing pieces of knowledge on further learning, where the application of these pieces is dependent on the student's perception of the salient features of a specific problem.

Some research studies have suggested that separate concepts within children's ideas are structured (for instance, Osborne and Wittrock, 1985). These structures do not necessarily coincide with the accepted scientific ideas (Ruggiero, Cartelli, Dupre and Vicentini-Missoni, 1985; Noce, Torosantucci and Vicentini, 1988). These researchers described the structure of children's ideas about weight, gravity and air, and found that children connect gravity and air, but not gravity and weight. Bliss, Ogborn and Whitelock (1988) suggest that children's ideas can be interpreted as initiating from a common source which they refer to as "commonsense science", and this communality accounts for their structure. Di Sessa (1988) suggests that the extent of structuring in children's ideas should influence decisions about instructional methods .

In this study we seek an underlying structure in children's ideas about two instances of action at a distance : gravity and magnetism. We will extend the investigations of Ruggiero et al (1985) and Noce et al (1988) and will look for connections between air, gravity and magnetic interactions.

Children's ideas about gravity and magnetism

Children's ideas about gravity and their structure have been investigated and the following pre-instructed ideas were recorded:

(a) Definition of gravity

Gravity was defined as the velocity of falling bodies or the force that drags and keeps things down (Stead and Osborne, 1981). From this definition, children conclude that floating objects, such as a submarine in the sea (Stead and Osborne, 1981) or clouds floating in air (Bar and Zinn, 1992) are not effected by gravity.

(b) Cause of gravity

According to children, gravity is related to the vicinity of earth, and does not act in space or on the surface of the moon (Watts, 1982; Ruggiero et al, 1985; Noce et al, 1988; Sequiera and Liete ,1991). It is caused by magnetic properties of the earth (Bar and Goldmuntz, 1987).It can also be caused by earth's rotation (Stead and Osborne, 1981), when the earth acts like a centrifuge (Bar, 1993). Some children said that gravity is caused by air pressure (Stead and Osborne, 1981; Ruggiero et al, 1985).

(c) Mechanism for gravity

Gravity needs air as a conducting medium; it increases with height but suddenly stops when air stops (Watts, 1982; Bar and Zinn, 1992). The reverse relationship, air needs gravity, was suggested by pupils explaining chemical reactions as no air in space was attributed to a lack of gravity (Driver, 1985).

The structure of these ideas is summarized in figure1 (a, b and c).

INSERT FIGURE 1

Very little has been written about children's ideas regarding magnetism: Barrow (1987) found that children attributed the working of a magnet to a "type of gravity" and Finley (1986) studied conceptual change regarding magnetism with second graders, dealing only with the phenomenological aspects of magnetic attraction and not with any model that interprets it.

Previous research on children's ideas has suggested two reciprocal relations : between air and gravity, and between magnetism and gravity. Thus, the question arises, "Do children think that magnetic attraction also needs air as a conducting medium?" This supposed third connection between magnetism and the existence of air among children's structured ideas also derives from recorded children's ideas that forces act by touch (Gunstone and Watts, 1985) in Philopponus' fashion (Sarton, 1927). We assume that when encountering action at a distance, children invent a connection between the source of the force and the object acted upon (Mariani and Ogborne, 1991). Finding the connection between magnetic attraction and air as a medium in children's ideas guided our study.

INSERT FIGURE 2

Method

Target Populations

Two different samples were used in this study: a group in Israel (1) and a group in England (2). Both samples were from middling socio-economic status. There were almost equal numbers of boys and girls in each sample.

(1) One hundred and seventy-one pupils of 9-15 years in an elementary and junior high school in Israel.

(2) One hundred and six pupils of 9-14 years from a school in North Leeds in England participated. All the pupils who took part in the study had learned about magnets and about the solar system several times during the spiral science curriculum implemented at this school.

Instrument

Each test consisted of open-ended questions accompanied by graphics. Test (1) asked how a magnet attracts iron, if a magnet can act in a place where there is no air , and whether an astronaut could collect nails from the moon's surface using a magnet. Test (2) repeated the case of the astronaut on the moon and also asked if a strong magnet inside a space ship could influence a hammer in the hand of an astronaut floating freely outside his spaceship.

INSERT FIGURE 3.

Data analysis

Pupils' responses to the test items are described. These responses can be grouped into schema. These frameworks are presented using the following methods:

a) A simplified description consisting of a summary of each framework.

b) Illustrations of the framework, by means of extracts taken from pupils responses, with the respondents' age.

c) Comments about the ways in which the frameworks differ from the accepted scientific view.

Results

Responses to the test items are described below.

How does the magnet attract iron?

Similarly to children's ideas about gravity, participants' explanations about magnetism can be related to operational definition (a), cause (b) or mechanism (c).

INSERT FIGURE 4

(a) Operational definition of magnetism

A magnet is defined as an object that has a force that attracts.

A magnet:

"has an attraction force" (12 years, Israel)

"has force" (9 years 6 months, Israel)

"can exert force on iron" (13 years, Israel)

"has magnetic force" (14 years, Israel)

These answers can be regarded as scientifically correct, but they do not give a model that explains the source of the force or its mechanism.

(b) cause of magnetism

The cause of magnetism was attributed either to the existence of gravity or to the composition of the magnet.

"The magnet has special matter" (12 years, Israel)

"it has poles" (14 years, Israel)

"it contains invisible particles" (14 years, Israel)

"The particles are arranged in a special way" (13 years, Israel)

Attributing the cause of magnetism to gravity, establishes the connection between gravity and magnetism (see Figure 3).

(c) mechanism of magnetism

A magnet acts by exerting pressure, through waves or wind , or by emitting a stream of particles.

"*it exerts waves of attraction that attract the iron"* (14 years, Israel).

"*it emits wind that touches the iron*" (10 years, Israel).

"*it emits particles....*" (11 years 3 months, UK).

Some of the mechanisms suggested presuppose a conducting medium, such as air, for the magnetic attraction.

Can a magnet act in a place where there is no air ?

44% gave the accepted scientific answer, saying there is no connection between the existence of air and magnetic attraction.

56% claimed that the magnet would not act without air, they explained that without air:

"*the magnet can not apply any attractive force.....*"

"*it cannot reach the object....*"

"*the magnetic attraction waves cannot propagate..*" (14 years, Israel). This participant attributed the mechanism of magnetism to propagation of waves. Thus the need for air as a conducting medium was found among children's pre-instructed ideas.

Can an astronaut collect nails from the moon's surface using a magnet?

We changed the environment, moving from the earth's surface to the moon to check children's understanding of the operation of magnets within space context. Some of the participants related to the same ideas as given in the earth context, in describing the cause of magnetism or its mechanism.

(b) cause of magnetism in space

As on earth the cause of magnetism was attributed to gravity.

"*Where there is no gravity the magnet cannot function.*" (13 years 1 month, UK).

"*There is a little bit of gravity (on the moon) and the magnet needs quite a bit of gravity to pull anything made of iron.*" (13 years 1 month, UK).

"*On the moon there is no gravity. Thus the nails will float away from the magnet which is the opposite to (what happens) on the earth.*" (12 years 8 months, UK).

"*The magnetism on the moon has one sixth of its force on earth since gravity is only one sixth*" (14 years, Israel).

This last quotation attributes proportionality between gravity and magnetism.

(c) mechanism of magnetism in space

Two kinds of answers were given: the scientifically accepted answer that magnetic attraction occurs in all locations without needing a medium and without reference to gravity; air is needed as a conducting medium.

The accepted scientific view:

"A magnet will work on the moon because a magnet will work anywhere. It does not matter about the gaseous current around a magnet. A magnet is a magnet wherever it is" (12 years 2 months, UK).

"I imagine that the magnet will act on the moon and the iron nails will be attracted to the magnet because even though there is no air in space, the magnet does not need air to work." (12 years 11 months, UK).

"I think the magnet will pick up the nails, because if a magnet can work underwater, where there is no air, there is no reason why it should not work on the moon, where there is no air." (13 years 4 months, UK).

"*A magnet will act on the moon because there is no proof that magnetic force is just on earth and not on other planets."* (11 years 9 months, UK).

One explanation that can be related to classical atomist views:

"Obviously this (mixture) that makes up the magnet can go through any material ...gas and so on. If nothing is there, it must work." (12 years 1 month, UK).

Air is needed as a medium.

"The magnet will not act on the moon because there is no air for the magnetism to move through." (10 years 3 months, UK).

"On the moon there is no air for the power of the magnet to move around." (10 years 4 months, UK).

"On earth, a magnet can pass on magnetic waves through the air ,whereas, on the moon the waves might be too light and float around." (11 years 2 months, UK).

Sample 2 (UK) was not exposed to questions about the earth, and yet they propose the same cause and mechanisms as sample 1 (Israel). Some of these participants felt that both air and gravity are needed for the functioning of the magnet:

"On the moon there is no air and no gravity to help the magnet pick up the nails." (12 years 2 months, UK).

The following answers convey the differences perceived by the participants between the earth and the space environments.

The location should have magnetic poles:

"It will only work on the earth because there is magnetic north and the magnet is not strong enough to pick up magnetic north (when located on the moon)." (13 years 3 months, UK).

Earth is different from space:
"I think that a magnet can't attract (in space) what we can attract on earth and can attract what can't be attracted on earth." (9 years 6 months, UK).

This idea echoes Aristotle's precept that there are different rules in space. The opposing idea was also recorded:
"I think a magnet will act on the moon because it is the same as any other planet.I think it will attract nails because it does on earth, so it will anywhere else." (10 years 8 months, UK).

INSERT Table 2

The correct mechanism started to appear at age 10 and accounts for about 15% in the Israeli sample and 39% in the UK sample.The common alternative in the Israeli sample attributed the cause of magnetism to gravity; in the UK sample many suggested the need of air as a conducting medium, but this alternative decreased with age.

Can a strong magnet inside a space ship influence a hammer in the hand of an astronaut floating freely outside his spaceship?

To obtain more insight on children's pre-instructed ideas this question was added. The same ideas also occurred here (see Table 3), but with constraints on the question the number of correct answers decreased as pupils were preoccupied with the strength and fixed position of the magnet. The functioning of the strong magnet was explained in the following way: "*in a place where there is no air, the magnet's force is dissipated; but if the magnet is strong enough, some force still remains,.."* (13 years, UK); thus, the air functions as a conducting medium which concentrates the force. The discrepancy between the fixed magnet and the one in the astronaut's hand is rationalized in the following way : on the moon, the nails are perceived by some participants to be floating (no gravity) and the magnet cannot "catch" them, but the fixed magnet in the space ship is able to attract the hammer.

INSERT Table 3

Discussion

Relations between the concepts of air, gravity and magnetism

The aim of this paper was to check the relations between the concepts of air, gravity and magnetism in the pre-instructed ideas of pupils (aged 9-15). This investigation strengthened the findings of previous research about relations between gravity and magnetism (compare figure 1 with figure 4). Magnetism was explained as being analogous to gravity, caused by gravity and needing the existence of gravity to function.

While the connection between gravity and air has been thoroughly investigated, the connection between magnetism and air has not yet been recorded. This relation was sought in our study in three environments: on earth, on the moon' surface and in space. In the same way as for gravity children feel air is needed for the functioning of a magnet. Over half of the Israeli pupils thought that the magnet on earth needs air as a conducting medium. On the moon' s surface, more than a fifth of the participants from both samples related to there being no air on the moon and consequently the magnet cannot function there as there is no conducting medium. In space, with the constraint of a strong magnet, pupils thought up a model to account for the role of air by suggesting that air concentrates the force of the magnet. The very need for air is explained by mechanisms suggested for magnetism such as waves or wind that propagate through air.

Underlying cognitive structure

This study has shown that pre-instructed ideas about magnetism are well structured. Children suggest a mechanism for magnetic attraction, this mechanism leads to the need for air as a conducting medium. They also suggest an explanation for the effect of air on the magnet's attractive force. More over, similar mechanisms for both gravity and magnetism were suggested.

Misconceptions rooted in the History of Science

Though the three connections suggested in figure 2 are misconceptions according to the accepted scientific view , they are all rooted in the history of science. Children often explain the earth's gravitational attracting force as emanating from the magnetic properties of the earth, as in "the earth attracted it with its magnets" (Bar and Goldmuntz, 1987). This same idea occurs in the historical development of science, both in Gilbert's work, "The Magnet" (1600), and with Kepler's application of this idea (see figure 5) to the interaction between the sun and the planets (Casper,1959). The relationship between gravity and air was suggested by Gilbert (1600): "*Air (the common effluvium of the earth) not only unites the disjointed parts, but the earth calls bodies back to itself by means of the intervening air."* The relationship between air and magnetism appears in the writings of Guido delle Colonne, a judge in Messina in the thirteenth century, thought of air serving as a medium: "*In these parts under the foreign skies are the mountains of lodestone which gives power to the air to attract the iron."* (Motteley, 1922). The notion of action at a distance, which was so abhorrent to the ancients since it did not fit into their world, was also rejected by our subjects, who extended the need of a conducting medium to the magnetic force as well as to gravitation

Educational strategies

The structure found within children's misconceptions gains strength from their inter-connections, which have a mistaken logic and consistency of their own. How can we suggest an educational strategy to convince pupils of the advantage of the accepted scientific view? Children today are exposed to space technology and we have at our disposal means of demonstrating with a vacuum which were not available to scientists in historical times. We will describe two possible approaches.

Approach 1 uses children's exposure to space technology (Bar, Sneider and Martimbeau, 1993). Extending children's experiences of falling balls to "Newton's cannon" and further to earth satellites and the moon, pupils (aged 11 years) were led to the idea that gravity can act without air. Since pupils offer similar mechanisms for gravity and magnetism their beliefs concerning the magnet could be altered, but this last point has not been investigated yet.

Approach 2 uses vacuum demonstrations. A bell jar attached to a vacuum pump is needed. In the first experiment a spring with a weight is hung from the top of the bell jar, as the air is evacuated the spring remains stretched, thus showing that gravity can act in the absence of air. The second experiment has an extended spring with an iron cube attached to it, mounted horizontally in front of a strong magnet which does not touch the iron cube. As the air is evacuated from the jar, the spring does not contract, showing that the magnet continues to function in the absence of air.

These approaches, by extending what pupils can see to outer space, deal with the functioning of gravity and magnetism in the absence of air. By attacking one of the tenets of pupils' structured beliefs, we hope to bring them closer to accepted scientific views.

Conclusion

A three-concept construct connecting gravity, air and magnetism has been shown in this study; this construct has a parallel in the historical development of science. Indeed, many researchers have noted the parallelism that exists between the history of scientific ideas and students' cognitive development (ie.Fishbein, Stavy and Ma-Naim, 1989). The importance to science teaching of this analogy between children's alternative ideas and the historical development of science was suggested by Wandersee (1985) and by McCloskey (1983).

In general, a study of historical ideas can lead science educators to pinpoint critical questions to elicit children's alternative views. A practicing teacher can use a contrast between historical views and current scientific explanations to stimulate class discussion and start some conflict with pupils' previous constructions (Nussbaum and Novick, 1982). Combining these class discussions with experiments can lead to conceptual change.

Magnetism is hardly taught in our school systems and there are only a few studies about it. We feel that this is an important content domain since much of modern technology is related to electromagnetism. It is important to put magnetism in its proper perspective, showing relationships to electricity and not to air or gravity. This paper will serve to improve the teaching of magnetism by revealing children's incorrect structures.

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Table 1 : Pupils' ideas about the magnet (in%)

Age	Definition of magnetism	Cause of magnetism		Mechanism of magnetism		
		gravity	composition	like electricity	like gravity	by emission
9-10	33		38		8	
11-12	45	7	24	7	10	
13-14	18		50	5	5	5
14-15	36	7	18	3		5

* participants who did not answer are not included

Table 2 : Pupils' ideas about the magnet on the moon (in%)

Age	Mechanism of magnetism		Cause of magnetism	Cause & Mechanism	Location
	correct	air	gravity		
ISRAEL					
9-10	17	13	50		8
11-12	6	6	56		11
13-14	18	11	43		10
14-15	17	7	42		10
UK					
9-10	4	43	14	18	
10-11	43	26	9		6
11-12	52	26	13	9	
13-14	35	15	10		20

* participants who did not answer are not included

Table 3: Pupils' ideas about the magnet in space, constrained environment (in%)

Age	Mechanism of magnetism correct	air	Cause of magnetism gravity	Cause & Mechanism	Location
UK					
9-10	4	38	14	7	4
10-11	23	6	9		20
11-12	28	16	12	12	
13-14	25	20		25	20

* participants who did not answer are not included

Figure 1a - Definition of Gravity

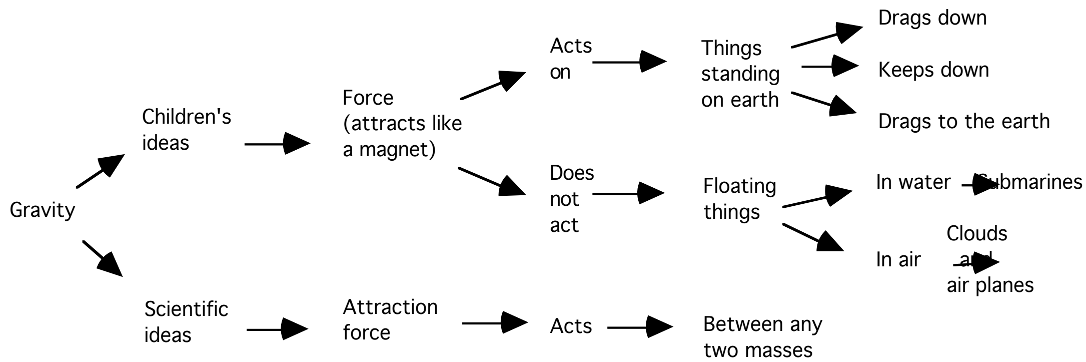


Figure 1b - Cause of Gravity

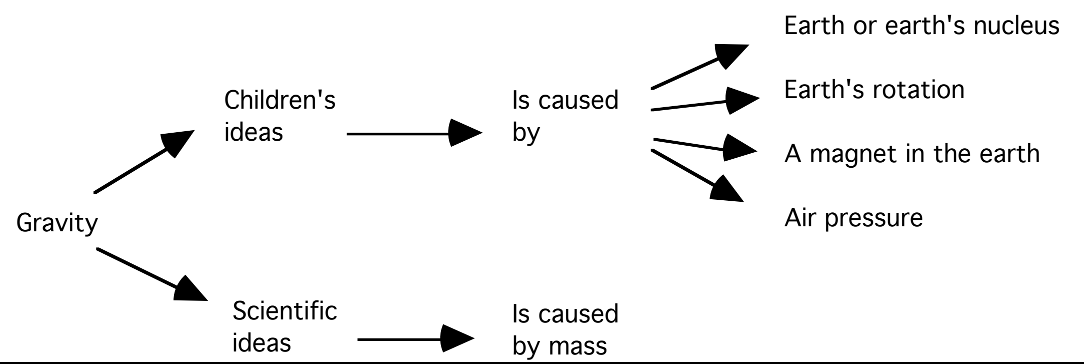


Figure 1c - Mechanism of Gravity

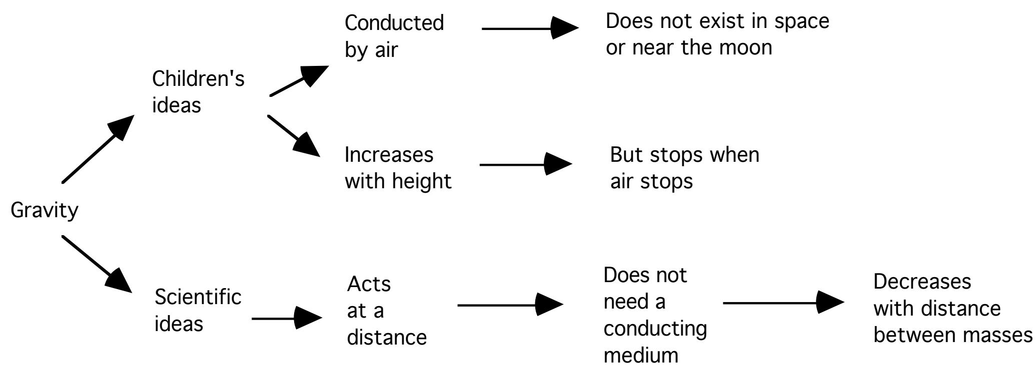


Figure 2

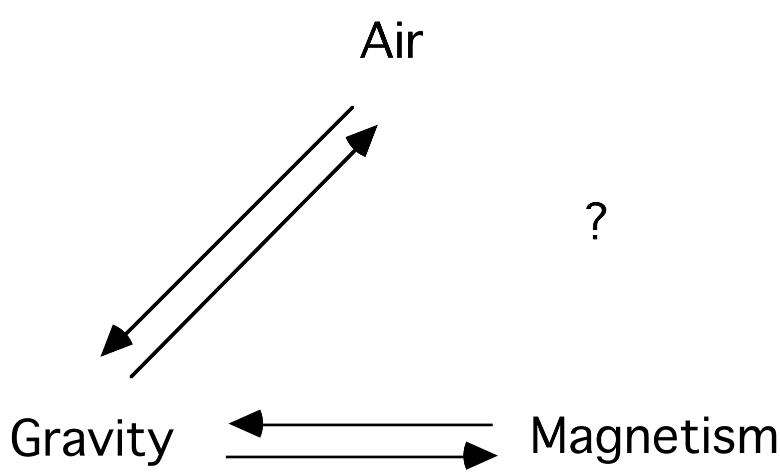
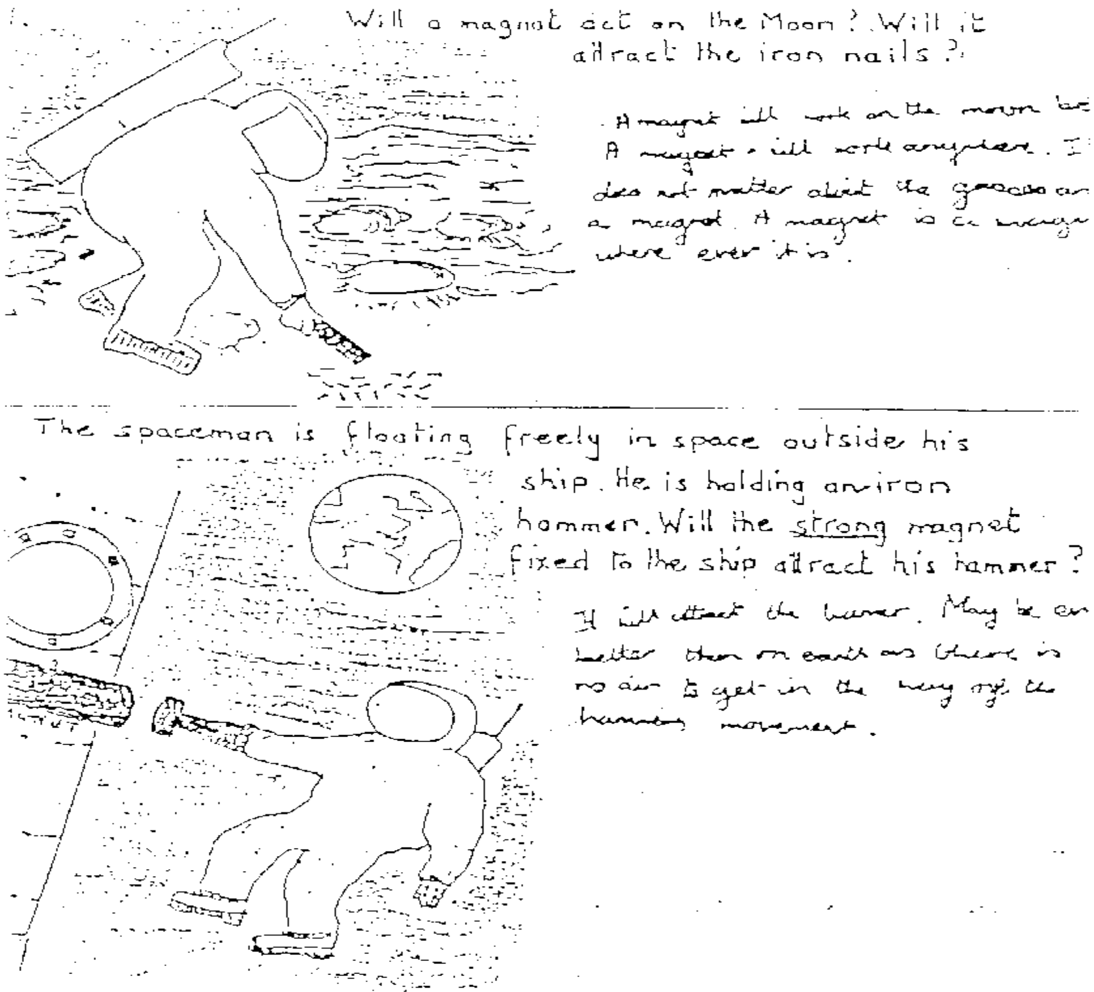


Figure 3



Will a magnet act on the Moon? Will it attract the iron nails?
The spaceman is floating freely in space outside his ship. He is holding an iron hammer. Will the strong magnet fixed to the ship attract his hammer?

Figure 4 - Children's ideas about the magnet

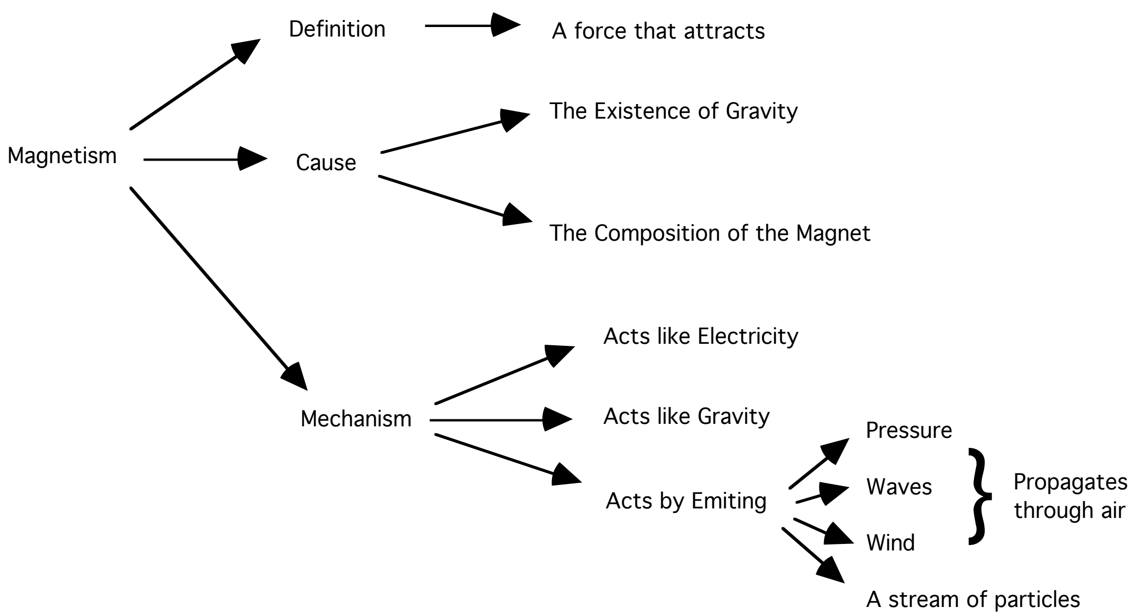


Figure 5