Exploring the sources of magnetic field and the interactions between them to interpret electromagnetic induction: a proposal of conceptual laboratory

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Introduction

Today electromagnetic phenomena are part of everyday life, even as concern pupils' toys. Scientific terms as "magnetic poles" and "magnetic field", become part of the common language. This popularization of physics terminologies however has been obtained through a loss of accuracy of the real physic meaning of these quantity. In scientific knowledge the problem of the correlation between the everyday and the scientific knowledge is one of the main problem of learning (Pfundt & Duit, 1993), is therefore necessary, in the framework of the Model of Edicational Reconstruction (Duit et al, 2005) to project inquired based learning paths (McDermott, 2004) in which students are personally involved in minds and hands-on experimental activities. With the aim to investigate how pupils develop interpretative ability to explain situations and artifacts from the results of several phenomenological investigation of physic quantities, a specific activity was designed in the framework of the Cognitive Laboratory of Operative Exploration (CLOE). CLOE labs are laboratories carried out by a researcher on a specific topic, based on a semi-structured interview protocol, that represents an open work plan built through the proposal of everyday life scenarios in which everyday common situations are studied following narrative reasoning by means of simple hands-on apparatus (Michelini, 2005).

Research questions

In this work three research question were investigate: RQ1) how an operative exploration may help students to identified and organize electromagnetic phenomena; RQ2) how the exploration and the comparison between phenomena is useful to help students in the interpretation of artifact; RQ3) how exploratory elements are reused by students in the interpretation of artifacts.

Context and Sample

The experimental activity was done in an informal context during a science festival – Mediaexpo 2009 – involving 135 middle school students from eleven to fourteen years old (6th to 8th school grade). There was 7 classes involved: one of 6th grade (20 students), three of 7th grade (60 students) and three of 8th grade (55 students).
Activity is divided in two phases: 1) an inquired based explorative phase; 2) a structured analysis of an artifact.

During the inquired based learning path pupils worked in 5 members groups but each student had his/her own personal worksheet. Communication between groups was not interdicted and after each proposed experimental exploration of a specific phenomenon there was a class discussion in which students organize their observation and learn how to draw conclusions, share and defend their ideas and challenge them with opposing perspectives or argumentations.
The equipment used by each group during this phases is: 6 compasses, 1 cardboard (A4 sheet dimension), a pair of big magnetic plates (with a surface of 10x20 cm) with their holder, analogical micro-ammeter and many coils with different surface and number of circumvolution and conducting wires to do the connection between the coils and the micro-ammeter. As concern this activity the setup of the classroom is truly important: to avoid interference with the functioning of the compasses we used plastic garden table and we provide to spread around the classroom several everyday object (Hifi, computer, mobile phone…) and some laboratory object (coils, coils carrying a current, generator…).

Figure 1: Induction torch

During the structured analysis of the artifact, the analysis of a particular tools (an induction torch – Figure 1) was proposed to student that before, only looking it, and after, touching and experimenting it, had to describe on a structured personal worksheet the proposed artifact. After that a final class discussion were promoted.

Instruments and methods

The inquired base explorative phase consist of four learning macro-steps: S1) study of the compasses behavior (far away from other objects) ; S2) study of the compasses behavior near a magnet; S3) individuation of the magnetic field source; S4) discovery and study of the electromagnetic induction.
During the macro-steps S1, we proposed to students a first simple exploration of the Earth magnetic field using compasses as an explorer of a propriety of the space. Student during this step used the compasses and the cardboard. In this phase student had to answer on their personal worksheet to three specific question:


Figure 2: Compass

S1.Q1 After placed the cardboard on the table with a compass upon it (Figure 2). Which is the direction of the compass needle?

S1.Q2 Rotate the cardboard at an arbitrary angle; wait and observe the needle. Which is the direction of the needle?

S1.Q3 If we use more than one compass, which will be the direction of their needle? Try it.

After that (and each one of the all other steps) there was a class discussion concerning these first observation.

During S2, student started to explore the behavior of a set of compasses when they are placed near a magnets using a set of compasses.

S2.Q1 Paste 6 compasses on the perimeter of a sheet of paper (4 on the corners and 2 on the middle of the longest side – Figure 3). Then put a magnet between them. Which are the orientation of the needles?

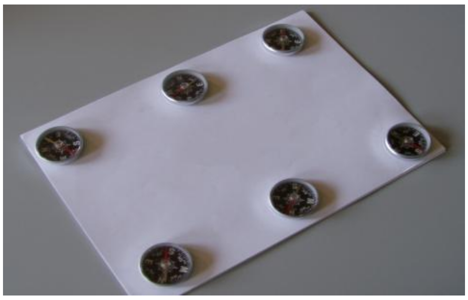

Figure 3: Set of compasses paste on cardboard

In S3 student are free to explore all the object present in the classroom with the set of compasses built in S2 looking for other type of object that are source of magnetic field. In this phase the setup of the classroom is pivotal: student must be able to find a large set (as large as possible) of common everyday-life objects.

S3.Q1 Are magnets the only objects able to change the orientation of the needles? There are other objects able to do it? Explore the room and check each object using the table of compasses. Which object can do it? (Which no?).

S3.Q2 Which are the common element(s) in the objects that can orientate the needles?

S3.Q3 Put a coil between compasses. How are the direction of the needle?

S3.Q4 Leave the coils between the compasses and connect it to the generator. What's happened to the compass needles.

In S4, after that they have shown that an electric current can generate magnetic field, they explore, whit a problem solving like approach the phenomenon of the electromagnetic induction. For this phase data were not collected on worksheet because an experimentation of this phase was already done and described in a previous work (Michelini & Vercellati, 2009).

At the end of the inquired learning based path, during the second phase, artifact is offered to students without any introductive explanation; the only instructions gave to students is concerning the methodology that they had to follow in the artifact analysis: initially students only looking at it had to say what is it, describe it on their personal worksheet and , after that, when all group had finished the first part, they can touch experimenting its functioning and, if they think it's necessary, they can improve their first description.

Data

As concern S1.Q1: 68% answer NORD, 20% report the cardinal point that appear to be under the needle tip (as shown in the Figure 2, in the compasses used the cardinal point are painted on a fix background), 7% direction is described referring to object present into the classroom and 5% don't answer.
Concerning S1.Q2: 80% highlight that the direction is always the same, 10% say that the direction change, 5% say that the cardinal point change and 5% don't answer

At S1Q3: 96% say that al compass needles have the same direction and 4% don't answer.

During the first class discussion the shared opinion is that whit this experiment we show that there is a propriety in the space that oriented the compass needles.

At S2.Q1 students, describing what's happening to the needle of the compasses pasted on the cardboard say: all needles point to the magnet (39%), needle of the compasses in the corner point to the magnet but the other two are parallel to the magnet (24%), compasses become crazy (20%), needles change their direction (6%), compasses lose their magnetization (5%), don't answer (7%).

At the question "Which object can change the orientation of the needles?" (S3.Q1) student answer writing a series of tables that are summarized in Table 1 and graphically represented in Figure 4.

Tested object	Can (%)	Cannot (%)	That's strange (%)
Coils with current	32,6		
Coils	26,7	24,4	
HiFi	21,5	12,6	
Computer	20,7	15,6	
Mobile Phone	17,0	3,0	
Fire Extinguisher	15,6	34,1	8,1
Blackboard	11,9	14,1	
TV	7,4		
Windows	5,2	14,1	
Generator	3,7		
Metal pipe	1,5		
Plastic table	0,7	8,1	
Professors' head	0,7	0,7	
Blackboard eraser	0,7		

Table 1: Which object can change the orientation of the needle?

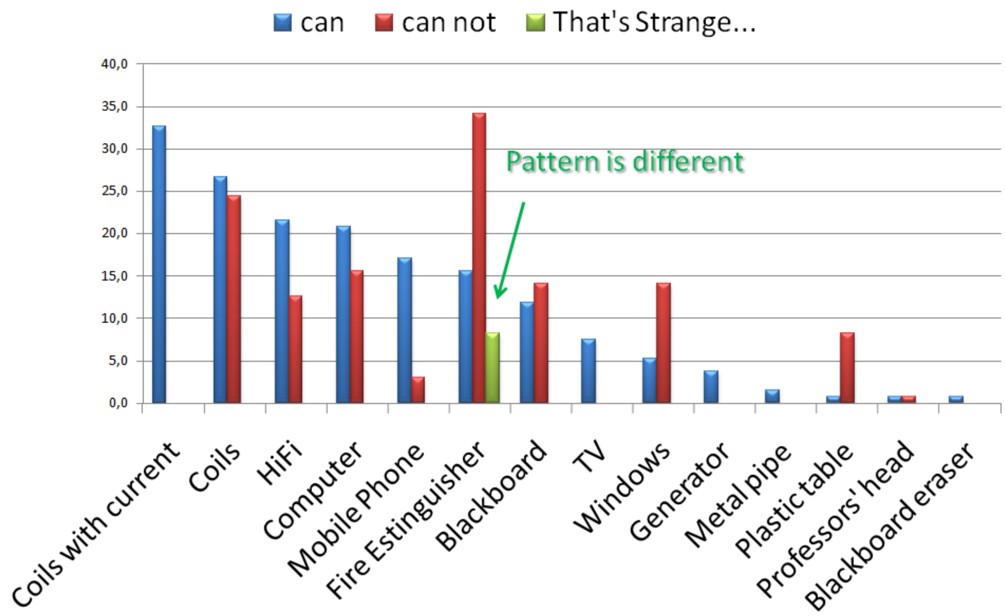

Figure 4: Which object can change the orientation of the needle?

In S3.Q2 student highlight as the common element into the object near which the compass needles change their direction is the presence of an electric current (61%); 39% don't answer.

This last conclusion done by a majority of the student, become a general class conclusion with the exploration proposed in S3.Q3 and S3.Q4.

During S3 discussion came out several interesting disquisition, particularly concerning the if the fire extinguisher has or not an own magnetic field (during the activity, the 'magnetic field' was introduced by the researcher only as label for the discovered that can reoriented the compass needles). In particular student highlight that when they go near the fire extinguisher whit the table of compasses point all to the object, but there are not needle that stay parallel to it, so they argue that it hasn't got an own magnetic field.

As said before, during the S4 phase wasn't collected written data. There was only a discussion in which student highlight the main characteristic of the electromagnetic induction (as for instance its transient nature) and explicit the different ways in which is possible to realize it.

Concerning the analysis of the artefact, 56% of the students said that it is an electric torch, another 38% of the students said specifying that it is an electric torch with a coil that produces energy and 6% don't answer.

Data analysis

Looking at the question S1.Q1; S1.Q2 and S1.Q3 is manifest as the experimental approach promote an evolution of the way in which student face the analysis of the phenomena. In S1.Q1, in fact, 68% of the student gives an answer as an assertion without looking at the experiment apparatus (i.e. "compass needle point to north") respect to 27% of them that referring their answer to the specific situation. Already in S1Q2 student focus their answers on what they think there are the important elements in the description of the phenomena: compass needle 80%, compass background and needle 15%. In S1.Q3 96% of the student refer their answers only to the direction of the needle.

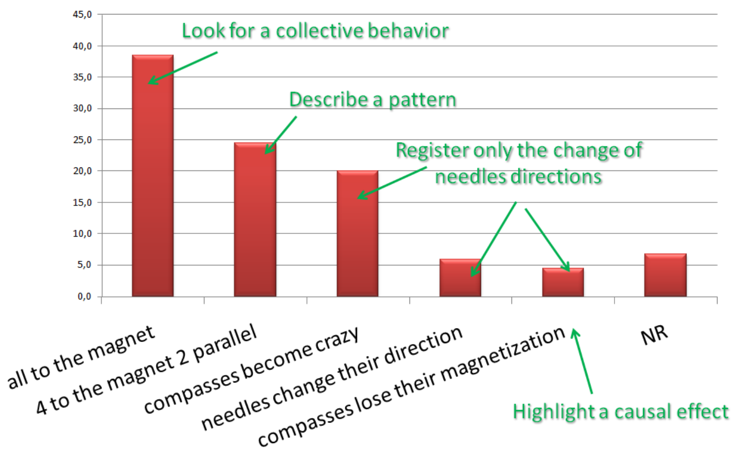

Figure 5: S2Q1 Analysis

Analyzing questions S2.Q1four different student approach are manifest (Figure 5): 39% of the students looking for a collective behaviour of the needles, 24% recognize the presence of a pattern, while the remaining 31% of the students who answered to this question register only a change in the needle directions. In particular 5% of the students highlight explicit a casual effect.

As concern question S3.Q1, how already mentioned, the more interesting part was the students discussion in which each object was analyzed and in particular, relating to the case fire extinguisher, students propose a method aimed at discerning if an object that is able to change the needle orientation have or not an own magnetic field.

Instead, during the artefact exploration phase is interesting to look at how student description evolves in from before to after that they can touch and analyze the artefact in an experimental way. In particular in Figure 6 are displayed which are the element that they use to describe the artefact. Is interesting to show how is manifest the pure structural element (as for instance the plastic skin) almost disappear after the experimental phase giving way to emerging functional elements (as magnet and lamp).

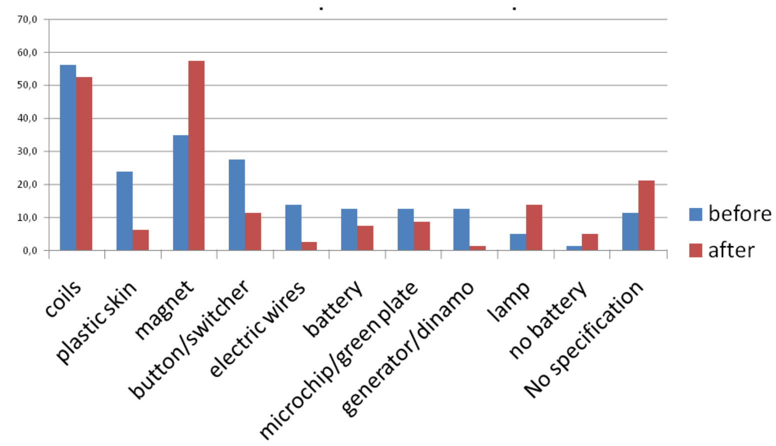

Figure 6: Elements used in artifact description before and after they touch it

It's more explicit when we look at the changes in the student explanation of the functioning of the induction torch (Figure 7). Structural description fall down from 55% to 6% and emerge two principal different approach to the artefact analysis: one looking at the physical principles (49%), the other looking at the technical principles (26%).

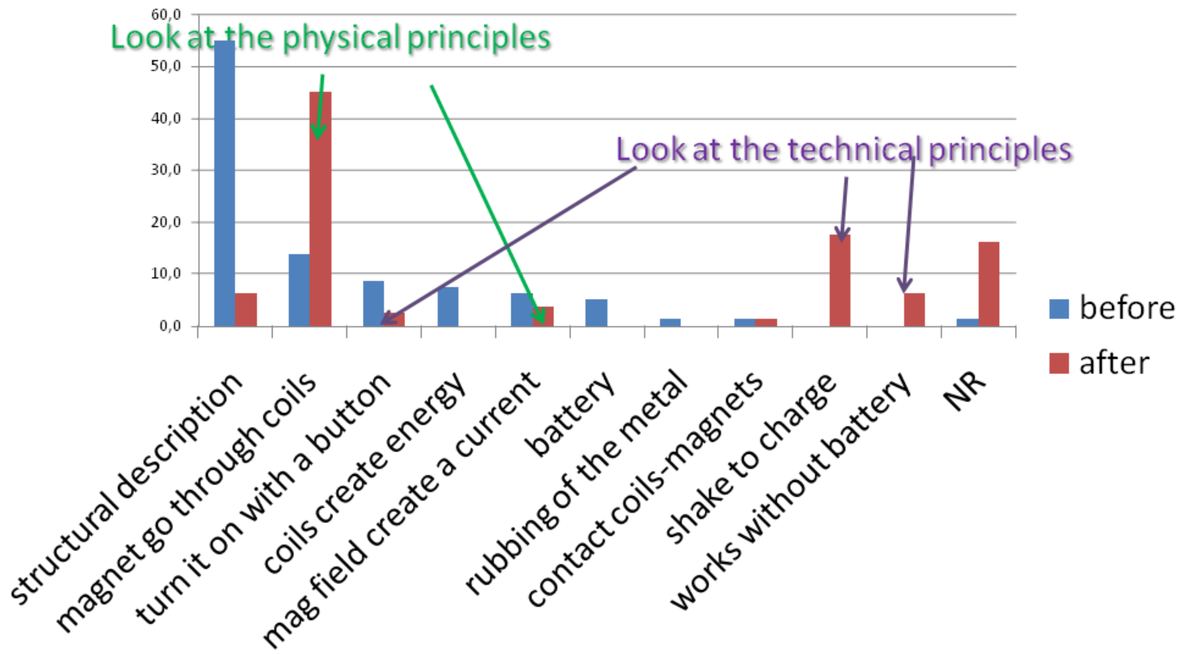

Figure 7: How does the artifact work?

Conclusions

From this experimentation emerge tree main important results: 1) an operative approach helps students to focus on elements relevant to processes and switch from a structural to a functional description; 2) comparison and analogies between artefact elements and explored ones allow student to re-use their preview discover into the interpretation of the artefact; 3) Experimental exploration allows and promote the switching between a structural to a functional description of the artefact highlighting so which are the scientific and the technical principle on which the artefact works.

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