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Metaphors and analogies proposed by perspective primary teachers to support the exploration of magnetic phenomena.

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Abstract. Analogies and Metaphors play an important role in primary science education to correlate abstract aspects and lived experiences, providing concrete meanings for pupils. They represent important educational tools that can help young pupils to approach towards abstract physics concepts like those related to magnetic phenomena. The significant presence of these phenomena in the world of 21th century allows pupils to explore and to familiarize with them starting from their childhood. These daily experiences offer pupils the opportunity to build spontaneously their own interpretative models about magnetic phenomena that influence also their future learning processes during the school careers. Recent educational researches have shown how pupils are able to master the interpretation of magnetic phenomena if those aspects are activated in the context of Conceptual Laboratories of Operative Exploration (CLOE). In order to improve the competencies of Prospective Primary Teacher (PPT) students related to the use of analogies and metaphors in education, a specific module of formative intervention was developed and proposed involving 92 PPT students enrolled at the University of Udine and 67 PPT students at the University of Verona. Initially, an overview of a well-experimented learning path was proposed to the involved PPT students and then they had the opportunity to try experimentally the proposed activities. After that, they discussed in small groups how to face magnetic phenomena with primary pupils with the use of analogies and metaphors. Finally, each PPT student was asked to produce an individual proposal that was shared within the small groups, commented and, finally, individually revised. In this paper, we present a preliminary analysis of the analogies and metaphors through which PPT students would introduce the magnetic phenomena observed in the GEI exhibition to primary school pupils.

1. Introduction

The international research in science education gives great attention to the use of analogies and metaphors (A&M) both by teachers and students, since they offer different educational opportunities and provide significant gains in the understanding of scientific concepts [1-4].

Analogies and metaphors take on a fundamental role into the constructivist approach as facilitators in the process of conceptual change [1, 5-6]. In particular, they can stimulate the construction of conceptual bridges between what is known and what must be taught and learned [4]. In particular, one of the main aspects highlighted by a wide literature is related to the role of analogies and metaphors as facilitators in the understanding processes of abstract concepts by pointing to similarities in the real world, promoting the construction of new knowledge starting from students' previous ideas [1].

The research presented in this paper was designed for Perspective Primary Teachers (PPTs) students in order to offer them innovative educational opportunities in the context of the Physics Education course. PPT students typically present considerable difficulties in the study of physics, which is caused in many cases by their lack of mastery in both the disciplinary contents (Content Knowledge – CK) and the interpretative models [7]. Usually, they think about laboratorial activities as complex experiences, difficult to understand and far from their everyday life. Consequently, it is necessary to provide PPTs with adequate educational tools that go beyond the disciplinary contents and that offer opportunities to put pedagogical knowledge in relation with the disciplinary contents [7]. It is necessary to structure learning paths that allow: (i) to analyze concrete educational examples, (ii) to study and experiment different didactic paths, (iii) to observe and apply various and innovative teaching methods, (iv) to know and experiment new tools for scientific learning. This goal can be achieved by promoting training activities in which the future teachers are encouraged to plan new teaching proposals and to reflect about them, in order to stimulate them towards an individual analysis and appropriation of the conceptual referents [7].

The training model for future primary school teachers proposed in this paper was designed and proposed by the research groups in physics education at the universities of Udine and Verona. The basic idea of our model for PPT students is to propose (a) disciplinary contents (Content Knowledge), (b) various educational examples and (c) laboratorial activities for the analysis of learning paths, conceptual referents and teaching tools [8]. In this perspective, they were asked to use analogies and metaphors in order to describe difficult (abstract) scientific concepts, since they facilitate the understanding of the abstract by pointing to similarities in the real world, providing “visualization of the abstract” [1]. More in details, we proposed PPT students to observe the section of magnetic interaction (as examples of abstract concepts) in the informal context of GEI exhibition (Games, Experiments, Ideas) set up by the Unit of Research in Physics Education (URDF) of the University of Udine. In fact, magnetic interactions include different learning difficulties for students (well known in literature), even if they represent phenomena that are present in the first years of everyone, thanks to toys and magnetic devices that allow children to become familiar with these phenomena and spontaneously construct interpretative models [10-11].

The paper is organized as follows: in section 2 the context, the working tools and the phases of the research are described; in section 3 the methods of data collection and processing are illustrated; in section 4 the preliminary analysis of the data and the main results are discussed; in section 5 the main concluding remarks are presented.

2. Context, working tools and research phases

This paper presents the results obtained in a study conducted including students of the degree courses in Science of Primary Education, 92 at the Udine and 67 at the University of Verona within the context of laboratorial activities carried out on magnetic phenomena in the academic year 2016/2017. PPT students of both the university were involved in similar training activities, through the exploration of magnetic phenomena in the informal context of the GEI exhibition. Such environment groups a set of conceptual laboratories that combine individual work of students with Inquiry Based strategies [12], in an informal environment that stimulates the reasoning and the explication of interpretative ideas for the construction of concepts, through the work in small groups [13]. The involved PPT students of Udine had faced (from a theoretical point of view) the main concepts related to the magnetic interactions and they had discussed the experiments of the magnetism section grouped in the GEI exhibition through the relative website, before the exploration proposed in our research. Instead, students of Verona were not introduced to such phenomena nor they had explored the experiments by means of the GEI website before the experimental exploration within the GEI context. On the contrary, only prospective primary teachers from Verona were introduced to the generic concept of interaction, from a theoretically point of view.

Both groups were involved in the exploration of the magnetism section of the GEI exhibition in a single meeting of about 4 hours. The experimental activities were preceded by the introduction (about 1 hour) of the concepts not treated by both groups (a first part dedicated to the concept of interaction for the students of Udine, a second part dedicated to the magnetic phenomena and the section of GEI exhibition through the website for those of Verona).

They were divided into small groups (4-5 people per group), each of which composed by students from both universities. They were stimulated to freely explore the entire section dedicated to magnetism for about 2 hours. Taking into account the main results of international literature about the use of analogies and metaphors [1], they were asked to think, during the exploration, of all the analogies and metaphors useful to describe the observed magnetic phenomena. After this explorative phase, students discussed inside their small groups, shared their ideas (about 1 hour) [14] and made a personal re-elaboration of all the activities carried out.

3. Methods of data collection and processing

PPT students presented individual reports: (a) in the form of laboratory notes, after three days, as regards students from Verona; (b) in more elaborate forms, after a week, in the case of students from Udine.

All the data collected were analyzed following the iterative process of the qualitative analysis [15], which allowed us to classify analogies and metaphors proposed by each PPT and to highlight their main characteristics. In particular, starting from the identification of the contexts in with the A&M had been planned, corresponding to the experiments grouped in magnetism section of the GEI exhibition, it was possible to classify these conceptual referents and to highlight the common elements that characterize the PPTs' analogies and metaphors. Moreover, from the students' descriptions it was possible to characterize many of A&M also with respect to the effects of each interaction.

4. Data analysis and discussion of the main results

We analyzed 563 analogies and metaphors proposed by PPT students, identifying three dimensions of analysis: (a) the physics situations that represent the experiments of GEI exhibition (as we said before, the context for the A&M), (b) the relevant aspects from the educational point of view for each analogy and metaphor, (c) the effects of interactions proposed in the analyzed A&M. A first interesting remark is represented by the comparison between the data obtained from the two different universities, since no significant differences appear after the qualitative analysis of the final reports, even if the two groups of students had different prerequisites. This is probably caused by group discussions, since each group was constituted by students from both the universities. This statement would need an in-depth analysis of the interactions between students during the group works, in order to understand the dynamics that lead students to such descriptions. However, we will not face this kind of investigation, because it would bring far from the topics of this paper.

As regards the first dimension of analysis (D1), almost the 70% of analogies and metaphors proposed by PPT students were focused on interactive systems (see Table 1), like interactions between magnets or magnetic poles (41%), between magnet and compass (8%) and between magnet and different materials (21%). The remaining A&M describe the physical quantities identified by students in the observed/performed experiments, like the magnetic forces (10%), the magnetic field (10%) and the magnetic field lines (1%). A number not negligible of analogies and metaphors does not propose descriptions of some physical quantities or interactions.

As regards the second dimension of analysis (D2), related to the relevant aspects from an educational point of view, the multiplicity of categories is greater than the first dimension, since students proposed for the same experimental situation more A&M, in order to highlight specific aspects in each analogy and/or metaphor. The Figure 1 shows the non-exclusive categories obtained by the qualitative analysis for the second dimension, with the total number of A&M identified for each aspect through the qualitative analysis.

Table 1. Physical situations proposed by students as context of their analogies and metaphors. The first group of categories represents the interactive systems, the second group represents the physical quantities.

	Category	Description	%
Interactive Systems	Magnet & Magnet	Interactions between two magnets or magnetic poles	41%
	Magnet & Non-Magnet	Interactions between a magnet and different materials	21%
	Magnet & Compass	Interactions between a magnet and a compass	8%
Physical Quantities	Magnetic forces	(descriptions of) magnetic forces	10%
	Magnetic field	(descriptions of) magnetic field	10%
	Field lines	(descriptions of) magnetic field lines	1%
	No description	No descriptions of some physical quantity or interaction	9%

Among the categories of dimension D2, one of them (directionality) groups students' analogies and metaphors (13) in which they describe only the field-lines' characteristic of directionality in the space. On the contrary, the remaining main aspects (i.e. reciprocity, distance, nature of interactions and nature of interactive systems) characterize all the A&M proposed to explain both the interactive systems and the observed physical quantities.

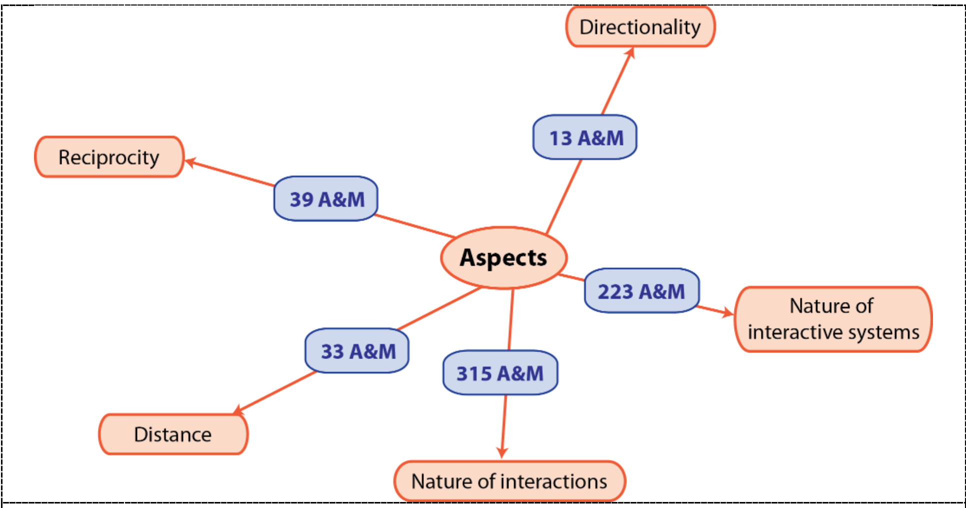

Figure 1. The non-exclusive categories of relevant aspects from an educational point of view. In the blue rectangles are indicated the number of analogies and metaphors identified for each aspect through the qualitative analysis.

The Figure 2 shows the relation of the four relevant aspects (i.e. reciprocity, distance, nature of interactions and nature of interactive systems) with respect to the interactive systems (introduced in Table 1). In most cases, students focus their attention on the nature of interactions (315 A&M) and on the nature of interactive systems (223 A&M). In particular, as regards the nature of interactions, we identified a group of conceptual referents (147 A&M) related to situations of real world, as for example the mother-hen that attracts chicks, the food that attracts animals, the sun that attracts/orientates sunflowers, the sweets that attract the children, etc.). Another group of analogies and metaphors (120 A&M) describes the interactive systems in terms of human relationships (between mum and son, friends or lovers), which represent a stereotypical contextualization in children imaginary. Such models group analogies and metaphors in which PPT students propose local references to single aspects instead of analysing and describing the whole processes.

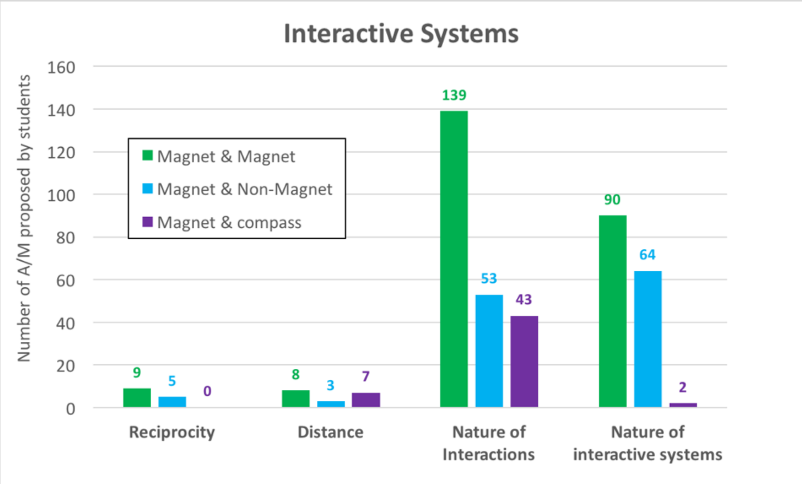

Figure 2. Interactive systems (Magnet & Magnet in green, Magnet & Non-Magnet in sky-blue, Magnet and compass in Violet) vs relevant aspects.

As regards the nature of interactive systems, it is possible to observe a group of conceptual referents (60 A&M) in which it is proposed a model of interaction between magnets and ferromagnetic materials. In particular, the behaviour of these materials is compared to a caterpillar that becomes butterfly, to a child who copies, to a chameleon, and so on. These analogies and metaphors put in evidence the idea according to which such materials change their intrinsic nature when they are close to a magnet.

Among the conceptual referents related to the nature of interactive systems, there are few analogies with the electrostatics phenomena (only 11 analogies) and this result is very interesting if compared with the well-known conceptual knot related to the electric vision for the magnetic phenomena, widely studied by international literature.

Finally, also in this case it is possible to find analogies and metaphors related to human relationships (between mum and son, friends or lovers) that are proposed to explain also the nature of interactive systems (71 A&M).

As regards the last dimension of analysis related to the effects of the interactions (D3), from the qualitative analysis we identified three main categories (Figure 3): Repulsion (17 A&M), Rotation and Rotation & Attraction (126 A&M) and Attraction, Movement towards and/or Contact between the interacting objects (196 A&M). In particular, analysing in depth the Figure 3 there is an import result that is related to the rotation, since it does not regard the behaviour only of the compass. In fact, 85 A&M describe the interaction between two magnets in terms of rotation and attraction. For example, the group of analogies and metaphors that describes the interactions between two magnets in terms of human relationships, in many cases, propose the idea according to which two lovers (or two friends, mom and son, etc.) "hug each other immediately if they are one in front of the other, while they turn around and then hug each other if they are turned from the back". This behaviour represents an important characteristic of magnetic interactions that usually is difficult to understand for students, as highlighted by international literature (in fact, it represents a well-known conceptual knot, also in this case widely studied in literature).

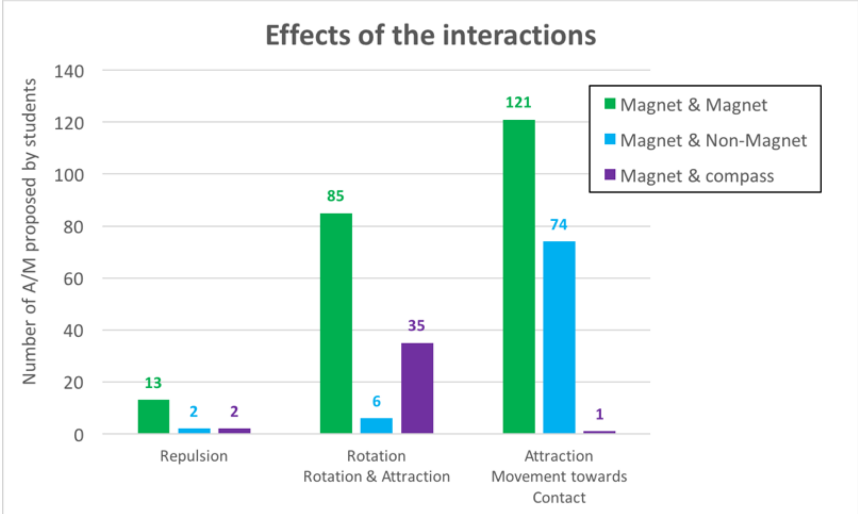

Figure 3. Interactive systems (Magnet & Magnet in green, Magnet & Non-Magnet in sky-blue, Magnet and compass in Violet) vs effects of the interactions.

5. Concluding remarks

The training model for future primary school teachers proposed in this paper is based on (a) concrete didactic examples, (b) observation of physics phenomena through hands-on and mind-on explorations in the informal context of GEI exhibition, (c) laboratories of analysis (about learning path, conceptual referents and educational tools) and (d) small-group works. Our study shows interesting results as regards the approach of PPT students towards magnetic phenomena. In particular, the use of analogies and metaphors stimulated PPTs' interest toward the exploration and the description of magnetic phenomena and offered us the possibility to put in evidence the main aspects that captured students' attention or that are more familiar to them. These results are even more relevant if we take into account both the learning difficulties well-known in literature about this part of physics and the difficult/hostile approach of PPT students towards scientific studies.

More in details, the first dimension of analysis shows the (low) level of abstraction for PPT students, which focus their attention on a descriptive-phenomenological level and do not propose interpretative models. On the contrary, they propose analogies and metaphors that describe the experimental situations (in particular the observed interactions: Magnet & Magnet, Magnet & Non-Magnet, Magnet & Compass), giving little attention to the main characteristics of abstract concepts like the magnetic field or magnetic field lines.

The second dimension of analysis allows remarking important elements that captured the attention of PPT students. First of all, there is (strongly) the idea according to which the ferromagnetic materials change their intrinsic nature when they interact with a magnet (compared to a chameleon, a caterpillar, etc.). Moreover, another relevant aspect (that emerges in about half of the proposed conceptual referents) is represented by the tendency to refer to emotional anthropomorphic aspects, by means of analogies and metaphors in which the human relationships seem to personify the interacting objects.

Finally, the last dimension of analysis allows to put in evidence another phenomenological aspect that captured students' attention, related to the fundamental characteristic of the interaction between two free magnets, according to which there is not repulsion when they interact each other, since they attract immediately or after rotations. In fact, PPT students propose situation in which there is a rotation not only when they consider a compass interacting with magnets or with the earth magnetic field, but also in the interactions between two magnets.

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