INFORMAL LABORATORIES AND PUPILS’ REASONING IN INTERPRETING ELECTROSTATICS INTERACTIONS

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Abstract Research in secondary school shows that it is particularly difficult the interpretation of simple phenomena of electrification and charge transport. The lack in simple charge interaction phenomena analysis appears to be important. We therefore organized activities of experimental exploration to support the building, from primary school level, of the concept of charge and its properties as guided reflection on macroscopic experiences. Informal and ludic approach appears to be useful in spontaneous reasoning analysis. In the context of the hands-on exhibition Games Experiments Ideas (GEI) in Udine and in Crema (MediaExpo 2009) were offered to pupils of 10 primary schools classes Conceptual Laboratories for the Operative Exploration (CLOE) on charge processes for phenomenological explorations in the light of the discussion of interpretative hypothesis. The process of building the interpretive reasoning of the phenomenology is explored and analyzed by means of the recording of small group discussions, interviews and stimuli cards/worksheet. The transition from a spontaneous vision of phenomena to a scientific one is the main focus of the analysis. The analysis of material collected during the activity provides information about students reasoning in interpreting the processes of charging.

Keywords Electrostatics; charge; primary school; reasoning; interpretation.

INTRODUCTION

Background, Framework and Purpose

Electrostatics offers many interesting aspects in developing scientific reasoning and formal thinking. It is the area where the electric nature of matter and some main concepts of electromagnetism (charge, potential and electric field) are built. It offers the opportunity to contextualize some constraints framing the subject content of physics: the principle of conservation (of the charge), the superposition principle, the concept of dynamic equilibrium. From a methodological point of view, electrostatics offers opportunities for exercising logical inference with regard to the conclusions that could be drawn from an analysis of macroscopic states and processes for the construction of reasoning aiming at an interpretation of the microscopic world: from changes observed at the macroscopic level after specific actions, evidence is obtained supporting the existence of the charge as an internal, mobile and twofold property of matter. This process is an example of scientific ways of looking in the study of phenomena and illustrates how science builds its hypothesis. Interest of science education research for electrostatics arises also from the problem that the lack of connection between electrostatics and electrodynamics is the basis of specific learning difficulties in this field (Eylon, 1990). The students’ macroscopic description of electric circuits is not linked to the microscopic quantities introduced in electrostatics. Other authors pointed out that previously acquired knowledge in electrostatics is re-used in the context of circuits in an unchanged form, without adapting it to the new context (Benseghir, 1996). Part of the students’ reasoning in electrokinetics come from a conceptual basis which includes a more or less intuitive knowledge of electrostatics, using the concept of electrical charge instead of the more abstract
concept of potential difference in the analysis of the circuits. The students’ focus is on the charges that they ascribe to the ends of the battery. Following these conclusions, specific interest arose for the reasoning in electrostatics. Research on learning difficulties in electrostatics can be divided into two areas. Some studies were carried out about the more formalized aspects of the electric field, Gauss law, electric potential (Törnvist, 1993; Rainsen, 1994; Viennot, 1999; Furio, 1998, Maloney, 2001), focused on high school or university students. Other studies are focused on the basic phenomena helping to build the first electrostatic interpretation: the process of electrification of bodies by friction, contact or induction and charge transfer (Guruswamy, 1997; Furio, 2004; Zubimendi, 2005; Guisasola, 2008). Again the involved students are in high school or university. We conducted inquiries at lower age (GEI) (Michelini, 2007) confirming the assumptions made for older students (Furio, 2004) on the spontaneous use of models already historically emerged during the development of the theory. The results of these studies show that simple phenomena of electrification by friction and induction are interpreted by the students according to four main models: Creationist, Halo-effect, Fluid, Newtonian. After researches on how electrostatics is learned, teaching/learning sequences and strategies are being developed to go beyond learning nodes that lead students to non-scientific conceptions (Guisasola 2008). The persistence, in spite of schooling, of these non-scientific models leads us to suggest the anticipation of phenomena exploration and the reasoning analysis for conceptual change process. This to exploit the attention to the phenomena that is part of the natural curiosity of children, and to avoid rooting of the interpretative models of common sense, consolidated and reused in several experiences (Viennot 1999, Michelini 2004). Following empirical studies on teaching/learning paths about basic electrostatic phenomena (Zubimendi 2005, Michelini 2007, Guisasola 2008, Mossenta 2010a and Mossenta 2010b) a proposal was designed, according to a vertical path from primary to secondary school level.

We present a research study carried out in a CLOE (Conceptual Laboratory for the Operative Exploration) context with 114 students of primary and middle school, during open informal activities offered to schools. The research is aimed to study spontaneous reasoning in context of emblematic situations and the reasoning evolution during games proposed for charge processes exploration.

**Rationale**

The study refers to a module of activities proposed to pupils. All activities are offered in a consistent and comprehensive way as a framework for exploration. The rationale of the intervention module aims to build the concept of charge as property acquired by the objects, after a preparation that makes them be in a state allowing them to interact in different ways by virtue of the property. All ways are based on two types of property, produced by entities necessarily always present inside the objects, that can be activated in different ways and responsible of the electrical interactions. These entities can move in the objects and from one object to another and keep unchanged their total amount. Some steps are stated for developing this interpretation process: from the simple observed interactions to the concept of charge as a state property of prepared objects. Our study aims to inquiry if it is possible to drive pupils to a construction of the interpretative framework through experimental exploration of different ways of electrifying objects, focused on the macroscopic properties of the electrical interactions. The proposed situations involve adhesive strips pulled from the same area, to recognize a property (repulsive effect) acquired from the tape as a result of the pulling; objects as plastic labels and straws rubbed with the same material, to generalize the situation; the same systems, but prepared with different materials, to recognize attraction and repulsion as different ways to interact, characterizing the property of the interacting systems.
accordingly; systems pulled or rubbed together, for a first introduction of the conservation of the charge.

We studied the extent to which children's reading of experiences involves identifying aspects scientifically relevant, descriptive and interpretative, according to the purposes for which the experiences were proposed. The research questions were therefore as follows:

RQ1: In what terms pupils read the behavior of the observed systems: descriptive or interpretive, according to a vision that considers the whole system or stops at a local view centered on the individual components?

RQ2: Do pupils identify the action that changes the state of systems? And that this will change the way they interact with other systems?

RQ3: Do pupils identify elements of explanation of the systems behavior? What are these elements? What are their features?

The underlying macro problem is the role for the learning of the proposal in its different aspects: cultural, cognitive, conceptual, methodological and operational. We studied the possibility of activating in the children interpretative tools, as reasoning looking to states and processes or closed logic and consistent inferences grounded on the experienced phenomena.

METHODS

In the first part of the proposal, tested in CLOE sessions, stimuli explorative cards are used (Martongelli, 2001; Michelini, 2004) helping to record ideas, and a strategy of Situation-Prevision-Experiment-Analysis, SPEA (Michelini, 2009): the presentation of a situation to the pupils, their justified prevision about its evolution as a result of a specific action, the experience and an analysis of the outcome compared to the prevision, referred to the reasons previously expressed. The activity involved primary school classes (10, fourth and fifth classes) and 1 middle school class: 114 pupils aged 9-11. It was conducted in small group sessions for an hour; the interpretation of experiences of charging by pulling/rubbing was proposed, and children individually filled the cards after the experiences and discussion on them. The analysis of these data allowed to keep track of the processes put in place during that activity. The answers written by the pupils on the worksheets were classified according to categories, related to the purpose of each step; they were defined a-priori from literature and previous activities and re-defined a-posteriori with the aid of the audio-recorded answers in interviews and discussions, to detect the pupils’ ideas and the kinds of explanations after each experiment, and the evolution of ideas and explanations during the activity.

RESULTS

Following the first experience, in which two strips of adhesive tape were approached after being pulled from the same place, all pupils identified a change in the state of the system observing the changed behavior of the pulled strips. Asked to specify the observed behavior, pupils gave answers that can be classified in two categories: I) descriptive (71/114 pupils), and II) interpretative ("they repel each other"/ "They do not attract each other"43/114 pupils). The descriptive category (I) refers the movement observed in the strips according to two subcategories: Ia) a single system whose parts changed their respective positions, "the tapes went away one from the other" (58/114 students), Ib) two separate systems that are deformed, "the tape is bent outward (13 pupils of fifth class). After the later experience of rubbing plastic labels and straws, most of this group change the answer (11 out of 13 pupils) and claimed that the two observed systems went away one from the other: they maintained a descriptive view, but gained a more global perspective during the different explorations. The
pupils of the other categories maintained their first way of looking at the phenomena during the different experiences proposed to them.

After observing the system behavior of the two tapes, pupils were required to identify the actions producing the observed behavior: almost all pupils (108/114) described actions related to the observation of system behavior, without being precisely the conditions that produced it: they are sometimes records of observed actions. These are the mechanical actions performed on the tapes (attacking/pulling off the strips) and their approaching after their pulling (bringing tapes one near the other); the action of pulling is identified as the triggering action by 88/114 students. The interaction with the table (attaching) is focused by a few (19) pupils. Almost as many pupils consider only the action making the state visible (approach) and not the action that produces that state (13 pupils out of 54 citing it). Very few (3/114) pupils cite all the actions responsible for the activating of the tapes. In a fifth class, 6/13 pupils use interpretative quantities and a model of supply when asked about the action performed on the tapes: "maybe we gave it the energy" / "we gave electricity with the strong pulling". This change of level is not repeated dealing with the following experiences.

Coherent explanations of what produces the behavior of the tape are given by 75/114 pupils. The interpretations are based on two kinds of elements: a) proper of physics or pseudo-physics (84): force, energy, electricity, B) proper of the context (18): process variables noted, such as materials or the procedure used to change the status of the observed systems. 58 pupils relate the explanation to the action of activation, according to 4 categories of elements of explanation: a1) materials and activation mechanism (10 explanations, 3 involving a mechanism: "it takes something from the material"); a2) energy (taken during the pull, 24); a3) electricity/charge (taken or created or produced during the pull, 23); a4) the action of pulling (1); 26 pupils link the explanation to the observed interaction: 25 pupils attribute the interaction to a force, magnetic for 23 of these ("because there is a magnetic force"), only 1 pupil claims a description; 18 pupils relate the explanation to contingent factors (heating, gravity, the glue). In the fourth classes the explanation (one for each pupil) is mostly based on an interpretative quantity (7 pupils do not respond, 18 use the idea of force), in the fifth classes explanations become complex and the explanations are based on several factors: "the glue that is here, magnetism, a kind of energy, electricity is created in the pulling". The same question proposed after the experiences involving different objects and ways to activate them produces a cue about the coherence of explanations: 10/73 pupils modified their explanations, changing the involved entity (6) or introducing the preparation or the change of state as explanation (4). 5/73 pupils enriched their explanations with a mechanism regarding the same explaining entity; 12/15 students of the same class modified the explanation after experiencing the action of rubbing plastic labels, saying that "there is something inside the label". A final discussion into a group of 11 pupils of 4th and 5th class confirm that pupils recognized the involvement of two objects in every experience; that the observed 2 behaviors of the systems were produced by the action of pulling or rubbing, the condition on the objects to obtain these behaviors, in terms of preparation: "When you do the same thing they repel each other, when you do not do the same thing they repel or attract each other". After the activity 16 pupils of 5th class and 13 of 4th class were asked to tell to a friend what is happening in 2 situations, proposed by two pictures of adhesive tapes repelling and attracting, and to explain him/her what happened in the tapes to produce these behaviours. 14/29 pupils express an explanation, 7 of them involving charge or energy ("In fig. a) the tapes attract because in one there is a positive charge and in the other negative. In fig. b) they go apart because the charges are both negative"), 6 referring to a preparation linked with the experiences seen ("In fig. a) the tapes approach because they were rubbed together. In fig. b) they go apart because they were pulled off the same material"), 1 referring to contingent and animistic causes; 3/29 pupils give an
interpretation in terms of interaction without elements of causality (“In fig. a) the tapes attract and in fig. b) they repel”); 12/29 pupils only describe the behavior (“In fig. a) the tapes come closer and in fig. b) they go apart”), as a movement of two parts of a system.

CONCLUSIONS AND IMPLICATIONS

The considerable number of pertinent answers to the questions, even in the starting activity, with pulled adhesive strips, suggests that the tasks are well-established for the pupils level. As regards the research questions, we argue that the reading of the behavior of systems shows a rather sharp distinction between the fourth and fifth classes. The fourth classes look substantially in terms of interaction, repulsion between the tapes, while in the fifth classes are limited mostly to describe the observed behavior of distancing. Moreover, in this case emerges a description that seems more attentive to the changed appearance of the single tape, which "leans", than to the relationship between the two tapes as an interacting system. The simplicity of the experiences has facilitated their reading, but not the process analysis. The majority of pupils in this group after examining later experiences noted the distancing one from the other of the interacting systems. This supports the need to propose a lot of experiences, varying conditions, to facilitate the identification of significant elements for the analysis of the phenomenology. The fact that the vast majority of pupils in fourth class of primary school read the experience in terms of interaction indicates that reasoning based on it can be carried out since this level of education; confirming it the majority of pupils in the fourth class still shows the forces when providing an interpretation of the experience. The reasoning in terms of interactions can be carried out from primary school level, with long-term thinking. The vast majority of students identified the pulling as the action that produces the new behavior of the system, but almost half of the students also indicates the approach, which makes visible but does not determine the interaction. Again, as confirmed by subsequent experiences of friction, providing many experiences helps to identify the role of the magnitudes involved. The explanation of the observed behavior is given by a good number of pupils, who resort to physical entities for the interpretation: this is mostly the outcome of considerations that involve multiple entities and mechanisms in which the interpretative magnitude plays an improper role: it is necessary to get used pupils to the strict reading of the macroscopic phenomenology to help them in acquiring awareness in the control of inferences. From data emerge that pupils often modify their previous idea and describe processes in more generalized way, less related to the single system/situation and to contingent aspects. Finally, changing the way of prepare the charged state, they tend to interpret the observed phenomena as result of a process of interaction between two subsystems or almost they tend to consider all the two sub-system as a whole. Observing the same process in different ways pupils overcome a vision linked to local descriptive/contingent details, looking at the whole system and process as such. This conceptual steps is usually activated by the SPEA cycle. The habit to propose to the learners only one experience (usually regarding induction) is not enough to produce adequate learning outcomes. Observing that the class where in a first time emerged mechanisms of explanation has come to identify the presence of "something" in the systems as an element of explanation, in advance of the planned steps in the path, the search for interpretation by pupils should be encouraged. To get that the identified entities are used in relevant ways, groups of different experiences are needed, which lead to highlight further properties of charge (in particular its mobility), while consolidate and clarify the basic interpretative idea. In this way the interpretation process is facilitated and new meanings are produced.

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