IL NUOVO CIMENTO **41 C** (2018) 126
DOI 10.1393/ncc/i2018-18126-4

Communications: SIF Congress 2017

Fisici Senza Frontiere: Physics laboratory-based activities for schools

S. Bertelli

Dipartimento di Fisica e Scienze della Terra, Università di Ferrara - Ferrara, Italy

received 11 February 2018

Summary. — The activities realized in the Physics Education project named *Fisici Senza Frontiere* are here presented and discussed.

1. – Introduction

Teaching science in Primary schools in Italy is mainly affected by the training teachers received and some of them do not feel confident in teaching science subjects. In addition, a few adopted science textbooks give fragmentary notions and there are limited possibilities to participate to hands-on activities. Starting from an outreach event organized by the University of Ferrara, we, as a group of young researchers in Physics, devised a project to foster science dissemination based on practical activities involving pupils in experiments and group discussions, making them playing the role of scientists. The recipients of this activity are mainly pupils attending the first cycle of the education system up to 14 years old, in the territory of Ferrara, Italy. We report about the developments of the project in terms of best practice activities to bridge science and society.

2. – The project

The Physics Education project *Fisici Senza Frontiere* [1] is carried on by young researchers in Physics of the University of Ferrara and of the National Institute for Nuclear Physics. It was instituted in 2014 as a by-product of an outreach event organized by the Department of Physics of the University of Ferrara since 2010. In this outreach event *Porte Aperte al Polo Scientifico Tecnologico* [2], namely "Open days at the Science and Technology campus" people have the chance to visit laboratories devoted to STEM research. The recipients of these visits can be divided into these samples: pupils up to 11 years old, pupils from middle and high schools (up to 18 years old), families and adults interested in science or motivated to discover the University environment. According to the recipients, two kind of visits are programmed: junior and senior. In the junior visit, children can approach several areas of science through short exhibitions related to Astronomy, Maths, Engineering, Computer Science, Physics and Earth Science. In this initiative groups of young researchers participate as tutors of these exhibitions and to make Physics attractive for kids, toy-based experiments are proposed to explore a specific topic that changes every year (such as light, optics, heat, pressure, matter). This science-related event can be seen as a fruitful out-of-school learning space under several points of view: for kids as well for teachers to deepen science knowledge and it is a chance for teachers and researchers to compare and share ideas. In this environment, talking to teachers from different schools, it emerged that some of them do not feel confident in teaching science and this kind of outreach events are very important for kids to cultivate a positive attitude to science. According to the Eurydice's report [3], the way in which science is taught in schools depends on many factors related mainly to the training received by teachers and the content of both school curriculum tests or examinations.

From the conversations with teachers it came out the idea to structure the exhibitions realized in this event in lectures providing pupils with a space to experience the opportunity of working as a scientist together with scientists. We thus created a group of researchers dedicated to the realization of this project in some schools of the territory. Teachers have been involved while structuring the lectures in order to optimize the topics treated as a function of the knowledge of pupils and the methodologies to adopt.

The primary school curriculum in Italy [4] includes integrated science and the Physics topics or concepts suggested to be treated in the guidelines are: atmospheric phenomena, astronomical phenomena, pupils should be able to identify the concepts of dimensions, weight, specific weight, force, movement, pressure, temperature, heat. Students should start building the concept of energy. They should observe, schematize and describe states of matter. In these guidelines there is a lack of continuity between different concepts.

In our project, we structured several didactic units related to different Physics topics collecting and analyzing materials from websites, video, science experiment books, using science kit existing already and making new ones with the help of technicians and professors of the Department. The materials used during the lectures space from low-tech to high-tech. The lecture takes place in two hours and is structured in dialogic talk, demonstration, group discussions and hands-on sessions. The children's ideas play a central role in the lecture. In the dialogic talk, pupils are required to share their knowledge and experience using language to explain their thinking and to reflect on the reasoning, they should feel that they are an active part in the lecture. When the lecture is accompanied with demonstrations kids are asked to ponder about the phenomena under investigation and to explain what is going on. We tend to privilege the kinesthetic learning by means of practical investigations, hands-on activities under our supervision or theatre-based session in which pupils play a central role in the explanation and the visual learning by means of video, drawings, schemes and diagrams. The topics explored during these lectures are: Heat and temperature, optics, electricity and magnetism, the Solar System, pressure and vacuum, atmospheric phenomena, forces and movement, the microcosm: from the atoms to particle physics. As examples I shall present three of them in the next sessions: heat and temperature, optics and electricity and magnetism. Every lecture is prefaced by a short discussion on what physics is and studies, then the structure of the scientific method is introduced and related to the figure of Galileo Galilei. When possible, we try to include some chronicles of History of Physics since we would like pupils to

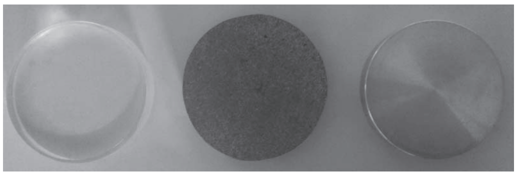

Fig. 1. – The three disk used to prove the melting of ice on conductor materials.

get familiar with the idea that science has is own time, that some phenomena took years to be understood and that science is animated and made by people.

3. – Heat and temperature

The didactic unit devoted to heat and temperature starts asking pupils to think about the definition of heat. They generally answer connecting heat to the sensation of something warm, sun or summer. This is a chance to us to introduce pupils to the scientific language, telling them that scientists to communicate their work, their research and studies use ordinary words and sometimes they invented new ones. We invite pupils to check on the dictionary the meaning of heat and usually the second definition is related to heat in Physics as a form of energy. After this we divide the classroom in groups of 4-5 pupils each and make them working together. We distribute different objects and we ask pupils to touch and classify them as hot, cold or neutral. They have to prepare a table that summarize the answers of all the components of the groups and they have to discuss their opinions. Then we ask whether the temperature of these objects is the same and the answer is 99% no, the temperatures are different. We measure the temperatures and we ask pupils why we feel them so different. After a guided discussion they conclude that it depends on the materials, in few cases (less than 5%) the answer comes directly from pupils. At this point we define thermal conductors and insulators and we let pupils play the role of a conductor or an insulator using a homemade model of atoms (small spheres connected with elastic cords) to explore what happens inside these materials when they approach a heat source. After that, we show different objects they see also in their home (like a spoon, a wooden spoon, a pot holder, a polystyrene ice cream box) and we lead pupil identify them in term of conductor or insulator and ponder about their usage in different situations. We define the temperature and the Celsius, Fahrenheit and Kelvin scales are presented. We say when we use them and (what pupils like the most) we made them see an image of these scientists to highlight that science is made by many people, discoveries and sometimes mistakes. The conduction of heat in solid at different temperatures is described using a picture that illustrated two objects at different temperatures (different colors) when they are separated and when they are put into contact. This drawing is distributed to pupils and they have to describe how the conduction of heat happens. The answer (95%) is that the heat goes from the warm to the cold one. To explore this fact we proceed with a demonstration in which we take three equal disks made of different materials: cork, plexiglas and metal, see fig. 1. Pupils are asked to touch these materials and to answer this question: if we put an ice cube on each of these disks, where does the ice cube melt faster? The answer (95%) is between cork and plexiglas. Pupils are astonished when they see that the ice cube melts faster on the metal disk and after having seen this they claim it is because the metal disk is a conductor.

Fig. 2. – A thermoscope made by pupils.

Students are asked to build a thermoscope, see fig. 2, using a bottle, water, food coloring, modeling clay and a straw. Pupils take the bottle filled partially with colored water and place the straw inside the bottle without touching the bottom; they thus create a cup with the modeling clay. When warming the bottle with their hands they observe the water raising in the straw. This is the chance to investigate the dilation in solid, liquid and gas. To appreciate the difference of the dilation in the states of matter, we show them the Gravesande's ring experiment. The last session is dedicated to convection in fluids and we used a toy-based experiment to investigate this phenomenon. We usually bring a lava lamp and we explain this in term of a slow-motion convection. To conclude the lecture we propose a quiz by means of a crossword puzzle.

4. – Optics

The unit starts with a definition of light and optics and we classify together with pupils different types of materials when they interact with light as reflective, transparent, opaque, translucent material. Using a flexible tube and a torch, pupils working in small groups can demonstrate the linear propagation of light. After that, students are requested to represent how the mechanism of vision takes place, the correct answer is around 50%. The other 50% represent the vision as ancient Greeks used to. In this stage is very significant how they communicate together sharing their idea and how they make decisions. Using a didactic kit, pupils explore the laws of geometrical optics. The didactic kit consists of a multi-ray projector that provides collimated light beams (adjustable in direction) that one can turn on simultaneously or not and make them impinge on different obstacles. We usually start with a plane mirror and students can verify using a

Fig. 3. – The top used to show an effect of refraction.

paper goniometer the reflection law. After that we use a concave mirror to determine the characteristics of images formed by these surfaces and we compared them with the images obtained using a spoon. Another topic investigated during the lecture is the refraction that pupils explore using the beams of the multi-ray projector impinge on objects of several shapes made of plexiglas. In everyday life pupils are familiar to refraction when at the seaside they observe fishes or stones above the water and they have an higher apparent height with respect to the actual one. Pupils can prove it using a top of a jar in which we have glued an image on the bottom of it. Pupils are invited to find a position in a room when they no longer see the image but only the border of the top. We fill it with water and the image is visible again. Most of pupils think that the image floats on the water but they realize this is not true when they come closer and they see that the image is still on the bottom (see fig. 3).

Using a light beam and a prism, pupils explore the dispersion of light and they can see the difference when we use a monochromatic light incident on the prism. We hence explain the rainbow. Using colored filters, we investigate how do we see the colored objects. During this didactic unit, we often explain the colors of the sky, to accomplish this we imply a box filled with water and some milk and we illuminate it with a torch. The water and the milk play the role of our atmosphere and pupils can observe how the white light torch passing through water and milk looks blue in the region close to the torch and looks yellow-orange when observing it through the longer path. Another topic treated during this lecture is the additive color synthesis and this is realized using a three-led kit (see fig. 4), pupils can interact with them, create different colors and vary the intensity to create the white light [5]. We tell pupils about the electromagnetic spectrum and we discuss about despite the fact we can only see the visible region, we use a large part the spectrum in our ordinary life, for instance we talk about the microwave oven.

5. – Electricity and magnetism

In this unit pupils explore the physical phenomena related to charging. The lecture begins introducing the atom and his components to end up with electric charges and the Coulomb interaction. We talk about the existence of the four fundamental interactions. After that we start defining the different types of charging. By means of balloons, cans, rice and polystyrene students, working in small groups, conduct experiments to investi-

Fig. 4. – The three-led kit used to explain and demonstrate the additive color synthesis.

gate the charging by friction and by induction and they are asked to ponder and explain what they observe. We treat the charging by contact and pupils build an electroscope exploring what happens when neutral or charged objects approach or touch the top of the electroscope. We provide pupils with a sketch that represents the phases of the experiment involving the electroscope and they have to complete the illustration reproducing by drawing the charge distribution inside the electroscope. The following demonstration is aimed to catch pupils' attention with an apparent magic using a portable Van de Graaff to make objects flying. Students are required to reason on what happens, on the shape objects acquired once charged and what they observe when they are discharged. After that the Wimshurst's machine is showed in operation and its working principle is illustrated by means of schemes or videos. At this point simple cases of circuits are introduced and pupils are asked to play the role of the components of a circuit, they have to form a chain (holding their hands) that closes on each end of a small tube armed with electrodes; when these electrodes are touched, the circuit is closed causing the LED lights inside the tube illuminate and a sound signal is turned on. Pupils experiment close and open circuits as they break the chain stopping holding their hands. Students have the task to create together a circuit that consists in a battery that powers a LED light. The equipment is composed by little pieces of sponge, copper and zinc foils, lemon, screws and rods. Students can test different types of components (little pencils, plastic ...) to identify insulator and conductor materials. In the last part of the session, magnetism is introduced using magnets and making pupils reason on the behavior of magnets when facing the same or opposite poles. Using different shaped magnets, pupils are asked to observe the displacement of iron filing when magnets are placed close to it. We make them ponder of the possibility to trace and visualize the existence of the magnetic field. We use a magnetic clepsydra, a toy-based experiment to investigate the behavior of iron filing when gravitational and magnetic forces act on it.

6. – Perspectives and conclusion

Starting from 2014 we went in different school in the territory of Ferrara and we took part to different science-related initiatives like festivals, University for kids lectures [6], museum-based activities in which we conducted interactive exhibitions addressed mainly to kids and their families. In 2016/2017, 600 pupils attending schools in Ferrara and in the countryside, Milan and Frascati (Rome) participated to our activities. During June 2017 we were involved in a STEM summer camp addressed to children in which we organized Physics Education activities in different days. Between September and November 2017, this project inspired a work-related program that involved 12 students aged 16-17 attending the High School *Liceo Scientifico Roiti* in Ferrara. The focus of the program was to study the profile of the expert in science communication. At this aim, the 12 students under our supervision, had the task of devising a Physics laboratory-based lecture for kids dedicated to Astronomy. They conducted this lectures during November 2017 in the presence of 24 Primary school classes promoting public engagement with science. In the activities proposed so far, an assessment stage was not taken into account. We proposed quiz (after the lecture) to some group of students to have a feedback on the topics knowledge and to probe the comprehension and the use of the scientific language. For the future we intend to include an assessment phase to develop a research on these activities and we are going to organize courses addressed to teachers to cultivate science literacy either at the pupil level or at the teacher level, providing teachers with the support and the instruments to make experiment in science teaching.

* * *

I would like to acknowledge the researchers who contributed in preparing and structuring the didactic units and participated to the project: Ilaria Balossino, Laura Bandiera, Pietro Bergamini, Paolo Bernardoni, Micol Boschetti, Martina Buiat, Silvia Calabrese, Enrico Calore, Elena Dall'Occo, Barbara Fabbri, Silvio Fugattini, Giacomo Gadda, Enrico Gamberini, Isabella Garzia, Giulio Mezzadri, Linda Polastri, Francesco Forastieri, Gaia Pupillo, Valentina Rolando. I would like to thank the Department of Physics and Earth Science of Ferrara University and the National Institute for Nuclear Physics to support us.

REFERENCES

[1] Fisici Senza Frontiere, `www.fe.infn.it/fisicisenzafrontiere`.
[2] Porte Aperte al Polo Scientifico Tecnologico, `porteaperte.fe.infn.it`.
[3] Eurydice, Science Teaching in Schools in Europe, `www.indire.it/lucabas/lkmw_file/eurydice/Science_teaching_EN.pdf`.
[4] indicazioninazionali.it, `http://www.indicazioninazionali.it/wp-content/uploads/2018/08/decreto-ministeriale-254-del-16-novembre-2012-indicazioni-nazionali-curricolo-scuola-infanzia-e-primo-ciclo.pdf`.
[5] Planinšič G. *et al.*, *Phys. Teach.*, **52** (2014) 94.
[6] Unijunior Università per Bambini, `https://www.unijunior.it`.