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Let there be light...

Abstract

"Let there be light..." is a project in the scope of the International Year of Light 2015 (IYL 2015) targeted at children of the first school grade.
Basically, it comprises nine recreational - scientific workshops that last for approximately 90 minutes. Each workshop is dedicated to a different topic, namely: bioluminescence, mineral observation, the rainbow, light-shadow contrast, battery production, just to name a few, and is designed, in different approaches, by a distinct team of scientists familiar to the scientific area focused. The activity starts with the dramatized storytelling of a children's story related to the scientific subject and performed by the team of the public library expert in this area. This moment takes place in an almost magical environment opening the door to the science topic light-related that would be focused later on. In the third part of the workshop, the children are invited to produce plastic works (*e.g.* drawings, constructions and models) inspired in what they have learned, and that are to be collected in a public exhibition held at the same institution at the end of the project.
In the present work, besides the description of the experience, you can find the critical analysis of the activity and the evaluation of the action by all the actors involved (project team and children/teachers that attended the workshops).

Keywords

Light; science communication; storytelling; transdisciplinarity

The *sprouting* of the idea – Introduction

All stories are sequences of casually-related events which allow us to unfold, step by step, in a smooth gradient, subjects that are complex *a priori*. Another great advantage of telling stories is that they leave a lasting impression, as they trigger the audience curiosity, driving it to want to learn more. At the same time, as the storytelling unfolds, imagination transports the public into the story and boosts visualization of more abstract or even intangible concepts (Ma et al., 2012). It is also stated that storytelling has a therapeutic capacity as it can switch the mood, develop imagination, increase knowledge and control and face emotions. Actually, this was one of the main themes analysed in the "International Seminar on Storytelling" that took place in March 2015, in Sintra, Portugal.

To sum up, stories make people cosy, comfortable and predisposed to listen. On the other hand, science is awesome but also a little intimidating to the general public. That's why stories on science are an excellent strategy to communicate the awesomeness of science to non-scientists. Screening only what happens in Portugal several initiatives that rely on this relationship have lately arisen. For example, "Once upon a time... Science for story lovers" is an interactive exhibition on science and technology, signed by Pavilhão do Conhecimento – Ciência Viva and inaugurated in October 2013. Its foundations are settled on the magical imagination of fairy tales and stories for children, and the exhibition explores phenomena/ concepts of the natural sciences such as physics, chemistry, mathematics, geology and biology, as well as of social sciences, relating them to our very real world (Nobre et al., 2005). More recently, Centro Ciência Viva de Lagos publicized, for the present school year, a program called "Stories with Science" composed of several ateliers with suggestive titles (e.g. "Message in bottle" and "The Seaweed that wanted to be a flower"), designed for children 5-10 years old, in which a practical activity on a science topic takes place after the storytelling. Also in 2015, several story books for children with some concerns on science, or at least with some strokes of science here and there, were published. "O cavalinho que queria saber a que cheira a Primavera" (The little horse that wanted to know how spring smells like) and "Mestre Carbono, o Cientista" (Teacher Carbon, the Scientist) by José Abílio Coelho and Filipe Monteiro, respectively, are just two examples.

It is our conviction that, to promote children's creativity and exploratory thinking, it is vital that those involved in their formal and informal education, should not only work together, but also resort to all forms of human knowledge, from science, to arts and humanities, in a truly holistic

approach. It was with this premise in mind that the team, composed by 12 members from different science, humanities and children education areas, launched into this project. And basically, the project consists of nine recreational workshops on science topics light-related, addressed to children from the first school grade (let's say, 5 to 10 years old). Here, a small parenthesis to justify light as the inspirational motto of all the workshops. Besides 2015 being decreed International Year of Light 2015 by United Nations Organization, light itself is a phenomenon omnipresent in our lives and transversal to all sciences. Returning to the conceptual organization, each workshop should be organized in three moments, either totally distinct or somehow overlapping, comprising a story, a practical hands-on moment on science and a ludic plastic activity, all of them ruled by the same topic. It may be relevant to say that part of the team had already been involved in a project in some way conceptually similar to this one, and inspired in the story "How to make orange colour" (Como se faz cor-de-laranja) by António Torrado (Nobre & Almeida, 2008). Last but not least, there are some evidences that topic-based learning, rather than traditional subject-based one, emphasizes the interdisciplinary nature of things helping students establishing links between disciplines and finding new areas of interest (Getting the Big Idea: Concept-Based Teaching and Learning, 2013[1]). Actually, this is the philosophy underlying the changing in "school" that Finland, often applauded for its great educational system, is about to adopt (Sahlberg, 2015). And this is also the line of thinking that drove the topic-centered workshops described in this publication.

Although the target group is typically extremely attentive and curious, the scientific approach has to be very elementary, as their background would not support deeper explanations. The phenomenon discussed in each of the workshops should be very visual/ pictorial and, in some sense, appealing to dazzle, in order to catch attention at the moment and to leave a seed for the future. To summarize, as far as we are concerned, the role of engaging in this type of workshops is to: (i) reveal that science is everywhere in our lives, (ii) show that the same topic can be seen from different perspectives, (iii) present science as a fascinating activity able to answer many questions of how and why and, lastly (iv) encourage open-ended explorations in order to ease making connections between subjects and different areas of knowledge. To the moment of this writing, five of the nine planned workshops, each one in a distinct scientific area, have already taken place and will be explained in more detail in the next section.

[1] Retrieved from http://worldview.unc.edu/files/2013/07/Getting-the-Big-Idea-Handout.pdf

Putting things to move - The workshops

Let there be light... In Biology - Are fireflies magical?

Almost all the children know the songs of Mafalda Veiga, being even able to "hum" them. But none of them knew the story of the firefly that feared flying, in the original "O Carocho-Pirilampo que tinha medo de voar" that Mafalda Veiga wrote for children.

The firefly is probably the first living being that children and adults remember as the one being able to produce light. So the story of this "blue firefly" was chosen to talk about the bioluminescence phenomenon and to introduce some basic fundamental principles that scientists have to consider in their investigations. The story was adapted (the tale is quite extensive) and performed by the BLCS' experts (Figure 1A), and at the end, the children were taken to the plastic activity room. Although few of the kids had had for some time fireflies in their hands, everyone knew "the magic firefly", symbol of the CERCI cooperatives that support children with intellectual disabilities. But are the real fireflies, the little animals, really magical?

The fireflies were brought to this workshop through a brief keynote presentation with appealing images that allowed to introduce this insect, not very pretty but indeed very bright. Using the word morphology, known by some of the children present, the insect's main features were identified and the firefly scientific name (*Lampyris noctiluca*) pronounced... The kids enjoyed repeating it! And what about the question, "do fireflies have lights or stars on their belly"? These insects have neither lights nor stars but they have abdominal "organs" capable of producing bioluminescence, a phenomenon that results in the emission of light due to oxidation reactions mediated by enzymes. Fireflies can only be easily found in the dark summer nights, but not anywhere. They prefer a "good environment", calm and without pollution, being this the reason why they are excellent bio-indicators.

Taking advantage of some passages of the story, children were led to understand that to solve problems, we have to ask questions and to formulate hypotheses (Figure 1B), a way to think about the possible consequences resulting from a given condition. After the animated conversation that took place sparkled by the topic, children were led to work together and to produce visual materials inspired on the fireflies and on its importance. Almost all of them drew or made models with reused materials, evidencing the main characteristics of these insects from the coleoptera order (a pair of antennae, two pairs of wings and three pairs of legs). Of course, the light located at the lower part of these bugs was also not forgotten (Figure 1C).

And we hope that the writing of messages to save fireflies in particular, and biodiversity in general, would result in a conscious and solidarity spirit that the "magic fireflies" are intended to stimulate.

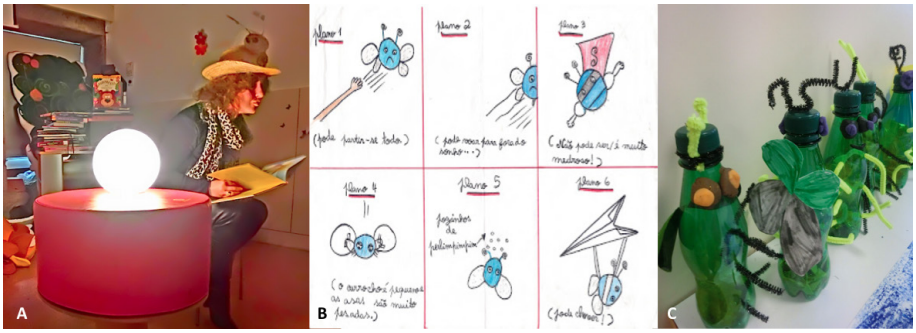

Figure 1: "Let there be light ... in Biology" moments. (A) Storytelling session. (B) To solve problems we ask questions and formulate hypotheses. (C) Children produced fireflies from reused materials evidencing the main characteristics of these insects

Let there be light... In Geology - How the light travels inside minerals?

"Two Grains of Sand" ("Dois Grãos de Areia" in the original), a short tale by António Torrado, was the story chosen to start this workshop and to carry the children to the universe of geology "in the adventures and misadventures of characters made of sand". And from the sand that constitutes the two grains, the talk went on through the minerals to some of its properties resulting from the "way" light travels inside them. Some of these properties can be observed by "naked eye" and others are revealed with the help of "magic eyes" (e.g. microscope) that "turn the small into big".

After the story telling that took place in a small auditorium suited to the effect (Figure 2A) the children moved to another space nearby where a small theoretic and practical presentation focused some concepts based on the relationship between minerals and light: colour, iridescence and double refraction. Children observed some hand-sample minerals (rock crystal, smoky quartz, opal, orthoclase, amazonite, calcite, fluorite, malachite, pyrite and chalcopyrite) noticing the colour and brightness diversity, both among different and identical minerals species. Afterwards, a hand sample of a polymineralic rock (granite) was shown, so that the children could identify the major minerals (quartz, feldspar and micas), mainly relying on its colour

and luster. After this observation performed by naked eye at the available light, the children were invited to observe a thin section of the same rock on the petrographic microscope (Figure 2B). The differences found were explained by the fact that polarized light permeating the minerals in the thin section was different from natural light, thus allowing the identification of the minerals present. Some minerals change their colour (usually ranging from blue to green) simply by the changing of the angle of light incidence. To illustrate this property known as iridescence, a labradorite gabbro sample was used. Children realized this characteristic by changing the angle of light incidence on the surface of the minerals through rotation of the rock, and thus observing different colours. Another activity performed intended to illustrate the double refraction, an optical property in which a single ray of light entering an anisotropic medium is split into two rays, each one travelling in a different direction. For this purpose a calcite rhombohedron (Iceland Spar) was used, placed over a paper with a word written on it. The rotation of the rock over the word resulted in its duplication.

At the end of this set of practical activities relating light and minerals, the children were asked to construct a cardboard calcite rhombohedron model (Figure 2C), in which they should represent the property of the double refraction.

Figure 2: "Let there be light ... in Geology" moments. (A) Storytelling session (B) Observation of a thin mineral section, using the petrographic microscope. (C) Detail of a calcite model construction.

Let there be light... In Physics - When light is colour

In this workshop the children were very young, mostly 5-6 years old, which was a great challenge for the team involved. The activity started with

the storytelling of the text "Mister Sun and Miss Rain" (O Senhor Sol e a Dona Chuva in the original), a short story by Teresa Teixeira that shows the importance of the sun and the rain to the arising of the rainbow. The story was staged in a very appealing and creative way by two animators from Lúcio Craveiro da Silva Library and members of the project, wherein one was the sun and the other the rain (Figure 3A). This scenario really caught the attention of the children and was of great profit to the next steps of the workshop, where several different day-to-day situations establishing a relation between colours and sunlight were shown. The children realized that colours are originated in sunlight. They watched the sunlight being divided into a multitude of shades, from blue to red. They also saw the same multitude of colours being reflected on the surface of sunlit soap balls or on the surface of a CD illuminated by the sun. Moreover, children observed their own clothes changing colours when they were successively illuminated by blue, green, red or white lights (natural light of the sun) and had lots of fun creating coloured shadows (Figure 3B).

In the third part of the activity, the children were invited to produce plastic pieces, mostly drawings, related to what they had seen and had been told in the previous moments of the workshop. Finally, to end in a great mood, children produced soap balls on the balconies, and watched them fly and change colours (Figure 3C).

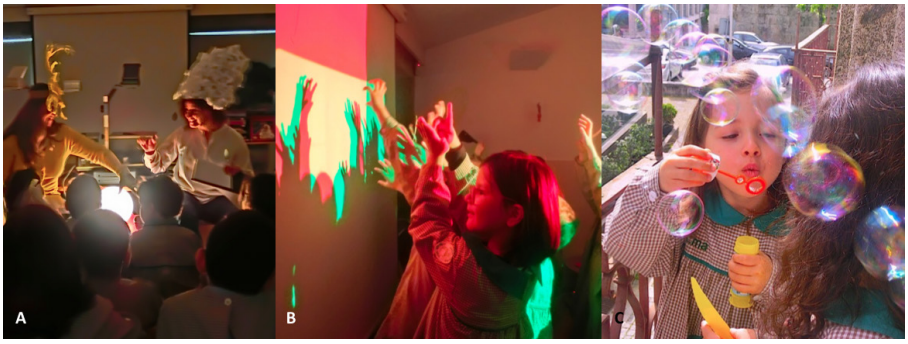

Figure 3: "Let there be light ... in Physics" moments. (A) Storytelling session. (B) Having fun creating coloured shadows. (C) Children produced soap balls on the balconies

Let there be light... In Mathematics – Measuring with the shadow

The story chosen to begin the session was "Mãe, não pises a minha sombra" (Mother, do not step on my shadow) by Ana Esteves. After the reading of the story, and using some diagrams, children were shown that it is possible to measure the height of a building by comparing its shadow with the shadow of a regular pencil. Additionally, the importance of the sunlight in this process was highlighted. This session involved sixteen children from the second grade. To work with the notion of proportionality was not straightforward (had the kids been older, we could have mentioned similar triangles or Thales' theorem). So, it was established that the "height of the building" equals the "height of the pencil" x "building's shadow measure" divided by the "pencil's shadow measure". After this, and using a spotlight and a pencil of 21 cm, some kids found their height using the correspondent relation (we measured their shadow and the pencil shadow and introduced these values on an excel file prepared for the occasion) (Figure 4A). Finally, the children measured themselves using a tape measure that allowed them to check how close the two sets of values were.

In the second part of the practical section, the focus was on the importance of sunlight in measuring time. Children were told about sundials, its history and were also shown some pictures of diverse sundials from different parts of the world. It was pointed out that these sundials are different, not only because of their different decorative patterns, but especially due the specific marks corresponding to the hours in different places. Moreover, children were alerted that the marks depend on where the sundial is placed and how the sun shines in that part of the world. Calling on the kids' creativity, the monitors asked them to create their own sundials (Figure 4B). As a matter of fact, with a paper plate, a little piece of play-dough and a pencil, anyone can create its own sundial. The kids marked the 12 o'clock spot and drew some decorative patterns as they pleased. The pencil was used as the clock pointer and it was attached to the plate using the play-dough. Then the kids were told how to finish up their sundials at school. At noon of a sunny day, they should put their sundials in the school backyard in such a way, that the pencil's shadow hit the 12:00 mark. Then, in intervals of one hour, the children should mark the position of the shadow and, in this way, they get a sundial. The children's teachers agreed to support the children with the completion of this task.

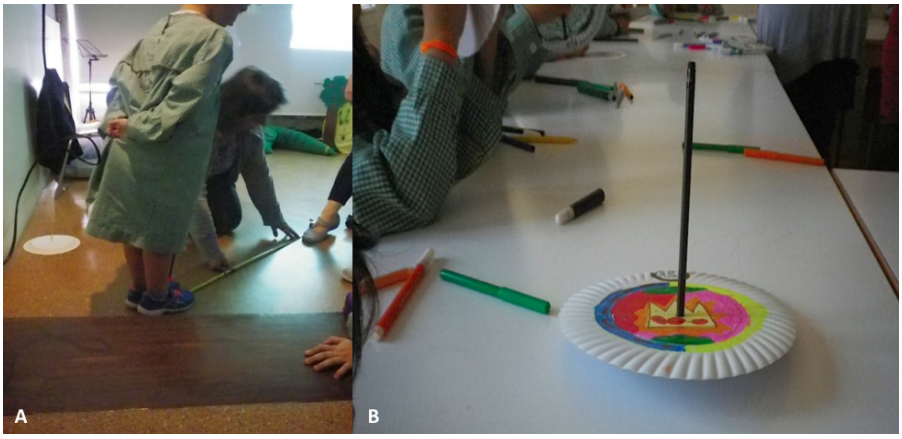

Figure 4: "Let there be light ... in Mathematics" moments. (A) Children estimate their height by measuring their shadow. (B) Sundials can be made with a paper plate, a little piece of play-dough and a pencil

Let there be light... In Chemistry – Artificial light, naturally!

In this workshop the motto was given by the story "The little boy that was afraid of the dark" ("O menino que tinha medo do escuro" in the original) written and illustrated by Susana Campos and Luis Lobo, respectively. To deal with the night shadows and the darkness, primitive man used fire. Today we have other resources, like electricity. The light that is not directly originated by the sun is usually classified as artificial, despite being produced by using natural resources. When we produce light by means of a candle or a lantern, we are actually performing chemical reactions. Fire is a chemical reaction called combustion that converts carbon-containing materials in a gas called carbon dioxide. Lamps produce light by a different mechanism, using the energy stored in batteries. When we turn on a lantern, we trigger electrochemical reactions (chemical reactions involving electrons).

In the suggested activity, the main goal was to explore the operation mode of a battery in order to produce light. The additional challenge was to construct a simple battery using common materials like copper coins of 5 cents, clips and lemons, and to use it to light up a LED which requires less energy than an ordinary lamp. Going into detail, in each lemon a coin and a clip must be inserted. The clip is connected to the coin of another lemon

using simple and accessible materials like springs of retractable pens and key rings hoops. To lit a small LED, a total of 4 identical sets of lemons must be used (Figure 5A). The clips that are made of zinc tend to be oxidized while the coins, coated with copper oxide, move towards reduction. Upon contact with the lemon juice, zinc clips oxidize transferring electrons to the coins, which in turn reduce the copper oxide to copper. As a matter of fact, the coins look brighter at the end! The electron flow (electric current) between the coins and the clips makes the LED placed between a coin and a clip, light up. The electrochemical reactions that occur in this homemade battery are similar to those that take place in commercial ones, producing electric current from electrochemical reactions involving metals and metal oxides.

At the end, the children decorated small frames in which the eyes of the characters were replaced by LED lights fed by common batteries (Figure 5B). A bright idea!

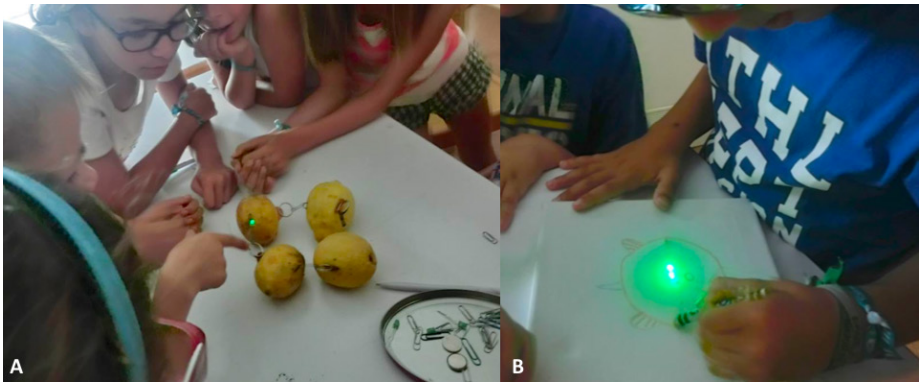

Figure 5: "Let there be light ... in Chemistry" moments. (A) Construction of a simple battery using common materials like copper coins, clips and lemons. (B) Children decorated small frames and lit them with LEDs

Keeping the goal in mind – Evaluation

After having carried out more than half of our project, we have already some consistent qualitative data that give us confidence in the choices made. And these data rely on the written testimonies of the teachers/monitors in charge of the children and responsible for enrolling them in the workshops; the SWOT analysis done by the team responsible for each workshop; the opinion of some external observers who, on a random basis, attended some of the workshops and; last but not least, the reaction of the target group, the children.

In what concerns the teachers (and in a sense the external observers), they are unanimous in several points, namely: the interesting association of the three moments Story – Science – "Art" calling out all the competences of the child as a whole human being; the friendly and diverse atmosphere that induces spontaneous participation; the language well-adjusted to the target public; the excellent coordination and planning of the workshops and also the interesting subjects that, most of them, intend to explore in the classroom. As regards to the project team, the commitment and the collaboration is evident and this, in turn, makes the experience extremely rewarding although also very challenging. It is worth remembering that the choice of the subject and the story, as well as the operation of the science – ludic activities is the responsibility of scientists, all of them university professors. As for children nothing said can ever be enough. They are genuinely curious, engaged, participative, enthusiastic, creative, which on one hand streamlines everything and on the other, creates some operational difficulties (to manage so much energy together is not easy!). And in this sense, the smaller the groups, the better everything works. These workshops have been attended by whole classes of 24 to 28 elements and 15-20 children would be the ideal situation.

Take home message – Conclusions

Workshops that include a short story on a subject, a simplified scientific activity on a topic mentioned in the previous story, and a final work that calls out the imagination and the creativity inspired on the topic (*e.g.* a drawing, a model, a sculpture or even a written statement), can be an interesting and productive strategy in a non-formal educational context, which, eventually, could be extended to the classroom.

Workshops that promote multi and transdisciplinary approaches to a scientific idea/ concept, allow a more universal and overall comprehension of such idea/concept.

This sort of workshops can be inspirational to the creation of new stories about scientific subjects (e.g. the light) that in turn will trigger other formal and non-formal educational activities.

Telling stories, by itself, could be a good initial instructional tool in the non-formal or formal teaching of sciences, as it sets the ambiance to absorb new knowledge,

To promote children's creativity and thinking, it is vital that teachers and monitors not only work and plan together but also resort to all forms

of human knowledge, from science to arts and humanities in a truly holistic approach.

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