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How Colours Are Created?

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Purpose

The previous (valid from last three years only) scholastic reform in Poland introduced "Science" as the main subject for the humanistic profile in lyceum. A grid of twenty five subjects, in a vague idea of the proposing experts of an interdisciplinary character, have been established by the Ministry. Subjects in the vertical contain physics, chemistry, biology and geography and in the horizontal grid define problems, like energy, water as a substance, human emotions etc. In the very private opinion of those experts the choice of subjects was rather causal. Moreover, no university in Poland prepared teachers according this reform and the Ministry allowed *any* teacher to deliver lessons in Science. This is highly harmful, as the majority of the adult society will lack the scholastic cv in detailed sciences. In the opinion of an educational expert from England (Chris Stuchbury, 2012) this an "upside-down system".

The goal of the present action was to define some interdisciplinary didactical paths, understand different aspects of them, publish their descriptions in didactical articles and posters, and finally implement them in a series of lessons for children of different (8-18) age.

Methodology

Perception of colours, starting from their physical principles, through the emission and absorption lines coming from the chemistry, to the biology of colour receptors in different biological species can be example of an interdisciplinary path through Science. The way of preparing such a project took several years. In the first implementation, within EU "Science & Society" 20772 programme entitled "Physics is Fun" we started from physics of colours: RGB basic scheme in the emission and CMYK scheme in the absorption. In a didactical poster we showed where different combinations of colours can be found in the surrounding us objects (Krzysztofowicz, A., Kruczek, Ł, Karwasz, G). The title of that work was "Pink glasses", as funny sun glasses for children were analyzed as optical filters.

More recently, we made a systematic separation between the physical principles (Karwasz, 2012) of colours appearing (refraction like in a rainbow, diffraction like on a CD or on the photonic crystals of the blue *Morpho* butterfly (L. P. Biró *et al. 2003)* and the chemistry (i.e. configurations of electrons in atoms and molecules). The chemistry enters into colours starting from the emission spectra of helium vs. nitrogen (both of them seem pink in the discharge tubes), to follow with the explanation of the observed hydrogen spectrum (atomic, but partially non-dissociated H_2) and a neon discharge (again pink, but containing also green emission lines). Physics and chemistry must be combined in order to explain colours in crystals, say precious stones, like Cr^{3+} ions in Al_2O_3 matrix, i.e. ruby crystal, Fe^{2+} in SiO_2, i.e. amethyst, Fe^{+2} in Al_2O_3, i.e. sapphire.

The biology enters in scene when we speak about IR detectors at viper heads, on UV perceptions by bees, on complex colour vision by some butterflies (Morell, V. 2016).

Results

A real challenge is not to talk about colours but to organize such a path into an entertaining interactive lecture. Analysis of colours requires spectrometers. In the case of discharge tubes simple diffraction glasses are sufficient. But already for children sun glasses an absorption spectrum must be recorded on a professional spectrometer. How can it be overcome in an interactive show?

Adding and subtraction of colours can be done with three, separate RGB LED lights. We start from an attempt to guess colours of artificial hair that wear two models chosen (in a complete darkness) from the public, see fig. 1a. As the colours of the hair are on purpose chosen not to be RGB (they are pink, yellow, orange, light green) the public, to their great astonishment (and also to the astonishment of the models) fails in guessing any of these colours. In order to explain didactically the basic colours we use an overhead projector and a set of didactical filters (Educational Innovations) and ready snapshots from objects around us (Krzysztofowicz, A., Kruczek, Ł, Karwasz, G).

Surprisingly, also in apparently simple physical objects like a rainbow (i.e after rain not in a glass prism) or soap bubbles complex colour patterns appear: due to the diffraction (rainbow) and to the destructive interference (soap bubbles and other thin films, like petrol on water). This is easy to show, but first the attention of the public must be triggered, asking a relative question: “what colour is the pink lamp?”

Entering more deeply into absorption spectra, today a highly amusing part of the lecture is identifying different organic components (coumarine, chlorophyll, quinine) inside commercially available beverages. A stimulated emission of different vodkas and grappas are particularly astonishing, see “equipment” in fig. 1b. We use a set of three portable LED lasers (red, green, violet). Combination of these lasers allows almost to determine the taste of beverages, without trying them.

The public reacts with interest, and their attention during a 60 minutes lesson is kept without problems, see fig. 1c. The didactical output, as obtained from discussion with single persons after the lecture is quite various: a director of the institute was surprised by the interactive play with models, a professional scientists (in Physics) was astonished by the presence of IR detectors on the head of a viper, a student liked the analysis of vodka with lasers.

Fig.1. Snapshots from interactive lectures on colours: a) astonishment of the public (and two models) that nobody guessed colours of the artificial hair under selective RGB illumination by LEDs; b) the discussion (with an university teacher) on the emission and absorption spectra requires a number of chemical species (cleaning agents from kitchen, alcoholic and non-alcoholic beverages, flowers etc.); c) a real challenge is to keep

attention of the public (at different ages) fir the whole 60 minutes lesson; d) teachers ask detailed explanations on preparation of the experiments (photo Maria Karwasz).

Perspectives

The main target group of our interactive lecture are teachers. In fact, as seen from their reactions, see fig. 1d, they are quite interested. Our aim is to furnish teachers with the ability to perform some simple experiments (tonic water with blue laser, spectrum analysis of fluorescent lamps using a CD as a diffraction grating, colours of soap bubbles, UV and temperature sensitive papers [6] etc.). From the requirements for this simple equipment we know that the message is perceived.

The perspective would be to license such lessons into professional institution dealing with the science divulgation. A second goal (unfortunately little realistic) would be to convince the decision-makers on the educational system in Poland that any reform can bring interesting outcome, provided a necessary time for preparing scientifically sound, didactically simple and publicly interesting interactive discovery paths (in any subject, not only Natural Sciences) is left.

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