Optics and children

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Abstract. Light and Optics are subjects that "naturally" attracts the interest and sympathy of children even from very early ages. In this communication, we present a serie of experiments and support material designed in this hands-on perspective, to be used to introduce the study of light and optics to kindergarten and early basic school students. Our hands-on investigative approach leads the students, aged 4 to 10 years, to observe the experiment and discover themselves, in a critical and active way, different aspects of light and optics. Preparing funny eye catching situations and experiments predispose the children to work, effectively, enjoying themselves while building up their self-confidence.

1. Introduction

Young children are always eager to learn to see to *discover* new things knowing and to understanding the world that surrounds them.

Children from 3 to 4 years are very much awake to the world, wanting to know and understand everything. They begin to build their own models based on what they observe and experience and from the responses they get from adults. However, not always they manage to find the answers they look for, or they are too complicated to be understood. Simple experiments may play an essential for achive the targeted development. Hands-on [1,2] activities are fundamental and the "natural" approach for these young students.

Vision has a major importance among our senses. It is an essential sense to gain knowledge of the world. In their every day life children cross all the time with light, images, colour and reflections. However, the explanations for observable phenomena are not obvious. Several misconceptions exist. For instance many children believe they can see because their eyes send light onto the objects. In this work, we present a set of experiments on Light, Colour and Vision, which aims, using very simple examples, to show how and what we see, as experiences can help us better understand the world around us.

The first concern of the educator should be, with this clear perspective in mind, to show… or better… to let the children to "see", to observe, to confront themselves with new objects, processes and situations.

Time is fundamental and should be generously given to the young students. Of course some "pressure" can be useful, in due time, respecting each one's pace. From early kindergarten years the children should "learn", should be led to work in a group to interact and cooperate with peers towards a common goal.

Care however should be taken by the educator in order to ensure that each student will have, in these group activities, the needed time to establish their own "knowledge" while guarantying that no children, apparently "faster", feels uncomfortable "waiting" for the others.

However, it is fundamental that each child understands, step by step, the importance of "cooperation", of listening to the other and to let others to share their findings, helping and accepting to be helped in the sake of a common goal.

How to do that?… a Portuguese popular saying (certainly with equivalents throughout the word!) "words are silver, silence is gold"… Educators should be patient and give time to the students and to themselves; open widely their eyes and lead the way smoothly affirmatively and discreetly. Words might be made of silver, but it is fundamental that the child is able to verbalize coherently their feelings, their findings and their opinions. In fact better results can be achieved if hands-on is complemented with a constructivist [3] approach and others like construcionism [4] and conceptual learning [5] allowing a deeper interaction with a wider range of children with different ages and background.

2. Light and optics for children

Being related to one of our main senses, being the eyes a major gateway to the world that surround us, light related phenomena are rather appealing to young children [6]. Young students readily realize the importance of seeing and the role of their eyes and of light sources. They are particularly attracted to the colour phenomena, to reflection and transparency, to shade and changes in luminosity…

Below we present a set of simple experiments that we designed for 4 to 10 years old students and that may serve as basis for teachers and educators to use in their classrooms and in informal activities [7].

We divided the experiments in three parts. A first one intends to introduce the role of the eye, and the idea that "we need light to see objects". At the second part we intend to show, using a simple model, how the eye works. Finally, the third part deals with light and colours and it is one of the most attractive for our young scientists.

Each experience highlights just a very simple concept. The methodology is as follows: the first is put a question, many children give answers to following a short discussion of the various hypotheses. The teacher must guide the discussion in order to help clarify the question well and using children's responses to introduce the experience to perform. The experiment is conducted with the participation of children, and at the end the initial question is repeated and takes place a new discussion guided by the teacher to clarify what really happened in the experiment and the concept in question.

2.1. Light and optics experiments

2.1.1. Part 1.

The main concept behind this first set of experiments was: we need light to see objects.

The experiments were design to demonstrate that:

1. We are able to see an object because the light emitted or reflected by the object enters the eye, through the pupil, and reaches the retina where it will be seen. The pupil controls the amount of light that reaches the retina allowing its stimulation (without causing damage).
Under intense illumination the pupil contracts limiting the amount of light entering the eye and avoiding glare and retina damage. On the other hand, when openning more light can enter the eye which is a natural response to darkness. So, in bright light the pupil is constricted and in dim light it is dilated. (Experiment 1)
2. There are objects that emit light and others that reflect light (Experiment 2). We see an object because either it emits light or light is reflected from its surface. Dark objects reflect little light while white objects reflect more light (Experiments 3 and 4.).

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Experiment 1- Observing how the pupil diameter changes with the amount of light that reaches the eye

Background: The experiment was design to show that the pupil reacts in accordance with the amount of light passing through to the retina. As the amount of light entering the eye diminishes, the pupil dilates allowing more light to reach the retina. When too much light is entering the eye, the pupil constrict and allowing less light to reach the retina.

Materials: penlights and mirrors.

Method: The children are divided into groups of 2 or 3. The room light is dimmed and penlights are distributed to each group. It is asked to one of the children to illuminate his/her eyes while the others observe the pupil constricts. This could also be done with children looking to a mirror while illuminate his/her eye. It is very important to use penlights not too bright in order to avoid ocular damage. Laser pointers or bright lights cannot be used under any circumstances.

Experiment nº. 2- Objects emit and/or reflect light

Background: There are objects that emit light (ie, light sources) and others that reflect light.

Materials: different light sources and several objects.

Method: The room is dimmed. Light emitting objects (of different types) and non-luminous objects are available and are shown. The similarities and differences between the various types of light sources and objects are discussed.

Experiment nº. 3 Brighter and darker objects

Background: The light is reflected from the surface of the objects. Dark objects reflect a small amount of light while white objects reflect more.

Materials: Several objects of different colours and a penlight.

Method: Several objects of different colours are placed in a black box with the front face open. The room light is dimmed leaving only a small lamp behind the box. The position of the lamp is gradually changed to allow some light to reach the objects inside the box. As the inside of the box becomes more illuminated the darker objects become progressively more visible.

Experiment nº. 4.- Light reflected by objects

Background: The light is reflected from the surface of objects. Black objects reflect little light while white objects reflect more light.

Materials: Mirror, penlight and cardboard of different colours.

Method: In a very dark room, each child place him self in front of a mirror. One hand holds a penlight on one side of the face in order to lighten the nose. The child is asked to observe his/her face in the mirror.

The experiment is repeated by holding a white cardboard with the other hand, parallel to the side not illuminated. The procedure is then repeated by replacing the white cardboard by a black one and then by cardboards of different colours. Finally the student replace the card a by a second mirror. Children record and discuss what they saw happening on the non-illuminated part of their face when using the different colours or the second mirror.

2.1.2. Part 2.

The main goal of these set of experiments is to illustrate how our eyes work. The experiments were design to explain:

1. How the image of an object is focused on the retina allowing us to see clearly a distant object. (Experiment 1)
2. How we are able to see at different distances. (Experiment 2)
3. Seeing "bad"… What is myopia and hyperopia. (Experiment 3)

These set of experiments were performed with a model of the human eye.

Experiment nº 1. How the image of an object is focused on the retina.

Background: in order to see an object its image must be focused on retina. This image is formed upside down

Materials: Human eye model

Method: Using a bright light source (a candle may be used under teachers supervision), images can be focused on the model's retina simulating the human eye imaging mechanism. The children may see that the image is formed upside down.

Experiment nº 2- How we can see at different distances

Background: In order to see objects at different distances, the eye should be capable of changes its optical power. This change is possible due to crystalline lens that his able to change its shape and, consequently, it optical power. When looking at a far object less power is needed so the ciliary muscle is relaxed and the optical power of the lens is diminished. To see clearly a near object the optical power of the eye should increase so the ciliary muscle contract changing the lens to increased its curvature and therefore, its optical power. This process is calling accommodation.

Materials: Human eye model with a lens that reproduces the behavior of the human lens.

The lens is a chamber constructed of a transparent silicone elastomer connected by tubing to a water-filled syringe. Water forced into the lens increases its thickness and curvature; the water elimination flattens the lens, changing its optical power.

Method: With the candle placed at a given distance its image is focused on the retina adjusting the water at chamber. Then, the candle is move closer to the eye and its image comes blurred. More water is need into the lens to change its shape increasing its power. The distance from the candle to the eye can be altered to see the changes in the lens to focus its image on the retina.

Experiment nº 3 – What is myopia and hyperopia?

Background: Many people suffer from a refractive error. The most known is myopia but there are others like hyperopia and/or astigmatism. The eye model can simulate refractive problems (that some children may suffer from).

Materials: Eye model and lens of different powers.

Method: Myopia and hyperopia can be simulated by changing the eye model length. Increasing its axial length, we are simulating a myopic eye. Now the image it is formed in front of the retina and far objects are seen blurred. In order to compensate this, divergent lens should be used.

2.1.3. Part 3.

Colour is the main concept addressed at this last set of experiments. The experiments were design to show that:

1. It is easy to separate white light' colours (Experiments 1 and 2).
2. We get white light by adding green, red and blue light (Experiment 3).
3. Getting yellow, magenta or cyan colours (Experiment 4).
4. The perceived object' colour depends on the light reflected from them (Experiment 5).

Experiment nº. 1.- White light decomposition 1.

Background: White light is "composed" of all the colours in the rainbow.

Materials: White light source, a prism or a diffraction grating.

Method: Using a bright white light source (placing a slit in front may help), a beam of white light is projected onto a white smooth surface (target). With a diffraction grating and, or, a prism, the light is decomposed, projecting the light spectrum on the target (it may not be easy to get all colours clearly visible. Children must look carefully. They will learn to be patient and resilient). Colour filters are placed in front of the beam. A final discussion on the experiment should be performed and conclusions set.

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Experiment nº. 2 -White light decomposition 2.

Background: White light is "composed" of all the colours in the rainbow.

Materials: White light source and CDs.

Method: CDs are distributed to the children. They observe the decomposition of sunlight (the light coming for ceiling' lamp or a flash light) into the rainbow. The experiment is then repeated with a pocket spectrometer.

Experiment nº. 3. and 4.- Mixing light with different colours.

Background: Adding green red and blue light allows us to get white light.

Materials: 3 light sources: green, blue and red (flashlights with colour filters may be used)

Method: Three light sources are used - one red, one green and one blue. The three beams are directed to one point of a smooth, not polished, white wall or board. Children must observed that with light is observed.

Children are also asked to make shadows with their hands and notice all the colours observed. The experiment was repeated with only two lamps connected at a time. The concept of subtractive colour mixing may also be addressed.

Experiment nº. 5. Reflected colours

Background: The colour of objects depends on the light reflected from them.

Materials: Light sources of different colours and several objects of different colours.

Method: This experiment is done using the same light sources used before and at the same positions. Several cardboard pictures of different colours (the cardboard should not be shiny) are placed on a black board. Those colour cards are illuminated with one of the lamps and repeated with each one of the other lamps and combinations of them. At the end the three lamps are switched on. (Especially for these two last experiments it is necessary to dim significantly room lights).

3. Brief discussion and conclusion

We decided to invite a group of elementary school students (ages 6 to 10 years old) to the university in order to perform these sets of experiments.

The activity was rather successful pleasing to students and teachers. Although stating their clear preference that the colour experiments were the most pleasant ones, the results were in general very positive, during the execution itself and in the follow-up activities undertaken back at the school.

Follow-up, in fact, should always be considered very important. These non-formal or informal activities (visits to labs, museums, science fairs or lectures) should always be followed of work sessions in the classroom exploring the motivation achieved and developing and or strengthening the knowledge transmitted/acquired. At the end of our activity a series of enquiries and quizzes were delivered to the teachers and asked to be returned for analysis and statistical treatment. Unfortunately so far we have not received back enough enquiries to perform a statistically significant analysis. Furthermore we distributed to the students material and short guidelines to build, on their own, a kaleidoscope and a simple pinhole camera (a muffin aluminum cup, a rubber band and a soft translucent paper sheet is enough…).

Being clear for us that the students easily and correctly are able to understand the importance of the eye in the process of seeing, we decided to explore a little bit the vision process. We used a simple model of the eye with a pupil, a rubber lens that could be inflated using a water syringe and a retina like displaceable target, which can be easily built. We expected the students to have difficulties in understanding the process or even accepting it since we were inside the eye! In fact only older students, 9 to 10 years old, were able to deal with it.

The age span covered, 4 to 10 years old, is rather large (especially as dealing with children). One must carefully deal with the differences, being flexible but always observing child's' reactions. From very early ages young children are strongly attracted to colours, in particular to bright principal colours, are fascinated by the wonders of colour mixing and they seem more attracted to additive mixing opposite to what happens with school students that before being presented to the issue had previous experience in mixing ink for paintings (the subtractive process). The hands-on manipulation of colour cards (especially if being part of games) is particularly effective.

In general the basic concept covered by these experiments (specially part 1 and 3) are readily understood by the young children that immediately after realizing the concept present a series of examples related to their own experience. Several children try to give examples of they own. For instance: "when electricity failed and lights went off I was afraid my mama leaves me alone at the dinner table"). This type of reaction happens quite often (normally older students are more "careful" expressing their feelings and ideas and restrain them selves) and is a good indication that some level of understanding of the concept was achieved.

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