

# Teaching the concept of dispersion based by diffraction of light to elementary school students

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## Abstract

This paper discusses the development and implementation of a practice based on Active Learning Methodology (*ALM*) with the aim of encouraging students from an early age to be interested in the world of science. The practical proposal is registered in the area of physics, especially in the field of wave optics, since it turns out to be very attractive to all ages especially for children.

This didactic sequence was developed with students from elementary school. The experimental sequence developed is composed by several experimental activities allowing to observe and describe the phenomenon of diffraction scattering, from the entering of light through a piece of compact disc (*CD*) which acts as a diffraction grating. The distance between the diffraction grating and the screen on which the maximum intensity markers are projected remains constant throughout the practice. Children light up the *CD* with a red pointer, mark on the screen the position of the different maximum intensity markers, then repeat with the green pointer and finally with blue; from observation and the answer of guiding questions proposed by the teacher, they begin to draw conclusions to diffraction for each wavelength. In this way, the child observes that the maximum intensity markers (diffraction orders) associated with each color are located in different positions. Later, children are enquired about the result of the process when it is repeated with white light. Immediately afterwards, the experiment is tried with white light to check it. Finally, comparing the results observed with pointers in different colors with the result out of the practice with white light, a relevant discussion starts, bringing students to the concept of diffraction scattering.

An important aspect is that the materials used in this experiment represents an important advantage in their application, since they are easily accessible (except for laser pointers in colors that are not very common in some places), so it is a practice affordable to any socioeconomic population besides being very striking to students.

**Keywords:** Scattering by diffraction, Active Learning Methodology, Basic Primary Education.

## 1. Introduction.

The light was one of the objects of study by Isaac Newton, which gave authority to defend the corpuscular nature of this one. The corpuscular model of light satisfactorily explained the phenomena of reflection and refraction; however, its theory presented inconsistencies in the explanation of the phenomenon of diffraction, which is explained by the wave theory of light [1].

The phenomenon of dispersion was studied by Newton in 1670, however since the seventeenth century another scientist named Grimaldi had observed that light had the ability to skirt obstacles in the same way as do waves that propagate on the surface of a pond; This fact contradicted the principle of rectilinear

propagation and strengthened the theory of the undulatory nature of light. Newton used a beam of sunlight and a prism to disperse the colors; however, it was not until 1917 that they separated the colors of white light using diffraction, thanks to the contributions made by Fresnel [1].

This paper describes the didactic experience used to teach the phenomenon of diffraction dispersion to students between eight and ten years of primary school. The practice was applied to a group of eleven students at a private school located in Chia municipality, on department Cundinamarca, Colombia. The materials that were used are easily accessible and inexpensive, so this practice becomes an activity of easy application for any socioeconomic population.

The activity is quite striking for students, especially of primary school because children at that age have not yet lost that capacity of amazement and curiosity that characterizes their age, in addition to that the optics devote its study to visual phenomena associated with light, something that is perceived visually and that attracts attention at first sight.

The experiment performed with the children consists of illuminating a diffraction grating with light of different wavelengths (blue, green and red), and indicating with color the position of the diffraction orders 0,  $\pm 1$  and  $\pm 2$ , by means of experimentation, the children corroborated that the diffraction orders are located separately according to the wavelength used. Finally, they were asked what they would expect to observe if the grid was illuminated with a white light source.

## 2. Materials and methodology.

The materials required in practice are inexpensive and easy to achieve, at least for the most part, laser pointers with red green and blue colors (the latter are still not very common in some places), white light flashlight, *CD* piece (Compact Disc), red, green and blue colored pencils, clay bar, white sheet and glue tape.

The didactic strategy used in the developing of the practice was the Active Learning Methodology (*ALM*), characterized by encouraging the student through the direct observation of the experimental results, to be the person who reaches the concept studied by comparison of their own hypotheses regarding what will happen in the experiment; the discussion of these with their peers and the contrast with the experimental evidence. In the *ALM*, the teacher has a role of guidance in the learning process, providing guiding questions that lead the children to conclude the concepts, with the observation and description of the experimental results. [2].

## 3. Experimental Procedure.

A white sheet is placed on the wall as a projection screen, using the clay as help support, the laser pointers, the flashlight, and the *CD* piece are attached and located, to form an experimental configuration as the one shown in figure 1.

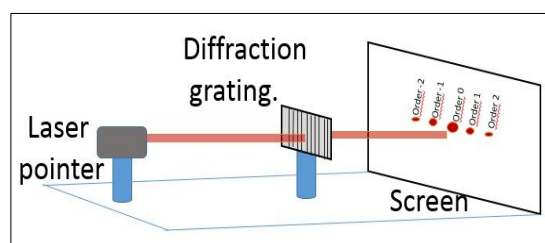


Figure 1. Experimental mounting illustration

With the red pointer, the *CD* piece was lit and the red points projected on the sheet were marked by writing a zero at the center point, and the numbers 1, 2, -1 and -2 respectively to the sides, as shown. See Figure 2, then the students were asked to write and draw individually the observed.

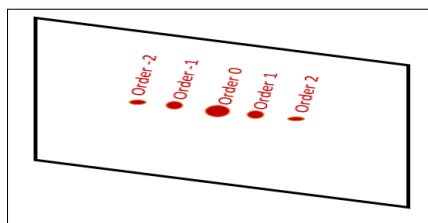


Figure 2. Diffraction orders observed with red marker.

To apply the *ALM*, students were instructed to individually write and draw what they believe they would observe when repeating the experiment using a green pointer, then changing to blue pointer and finally the white light flashlight, as shown in the figure 3.

They then discussed their opinions in small groups, socializing each group predictions, questioning them about their reason for each prediction.

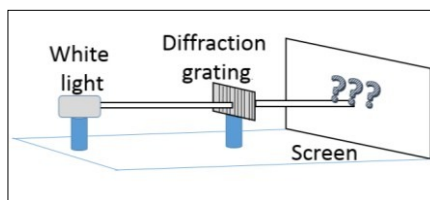


Figure 3. Prediction about the image on the screen.

Subsequently, each group of children performed the practice with the green and blue pointers and painted with the respective color the position of the orders  $0, \pm 1$  and  $\pm 2$ . Here you are warned about the precaution and safety of the handling of the laser pointers. Finally, they were questioned about what they expected to observe if they illuminated the piece of *CD* with the white light lantern, after the individual and group work, the group's predictions were socialized again and finally they were instructed to perform the lighting with the white light lantern.

#### 4. About the phenomenon of diffraction

The *CD* piece is a diffraction grating since it has a series of grooves, approximately 1000 stripes per millimeter, which allow the passage of light. The white light is dispersed by the grooves and deviated in different directions according to its wavelength (according to its color) [3].

The light of the laser pointers used initially is quasi-monochromatic and when it is impinged on the *CD* piece, it separates its diffraction orders, since the separation between the *CD* slots is comparable to the lengthwave of the pointers.

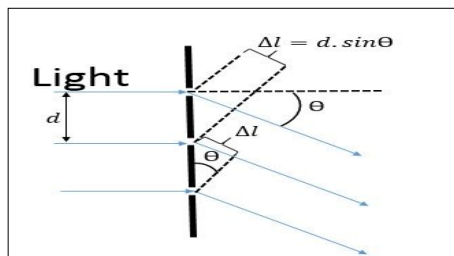


Figure 4. Diffraction grid operation.

When white light is applied, it is dispersed producing constructive interference at an angle  $\Theta$ , so that the rays of other parts of the *CD* piece travel an additional distance:

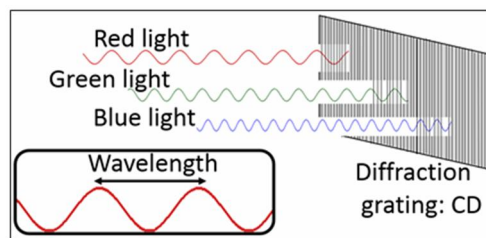
$$\Delta l = m\lambda \quad (1)$$

Where  $m$  is an integer,  $\lambda$  is the wavelength and  $d$  is the period of the grid (see figure 4).

The angular position of the main maxima obtained by illuminating a grid of period  $d$ , with a wavelength  $\lambda$  is given by [4,5,6]:

$$\sin\Theta = m\lambda / d \quad (2)$$

From this last expression, it is deduced that when illuminating with white light, each wavelength contained in the white color will be dispersed at a different angle and therefore the colors can be observed separated when collecting light on a screen [5]. Therefore, the first diffraction orders for each color can be located as shown in figure 5:



**Figure 5.** Relative location of the intensity maxima of the diffraction orders for the wavelengths corresponding to the blue, green and red colors.

## 5. Results

The diffraction pattern obtained by illuminating the piece of *CD* with the red laser pointer was the starting point for students to begin with the description of the phenomenon of diffraction in a grid at a given wavelength.

Then, when performing the experiment with the green and blue light pointers compared to the red, the students evidenced that all the colors coincide in a central point, while the maximums of the sides are located in different positions, as seen in Figure 6, where the blue diffraction orders are closest to the center, then the green ones and the farthest from the center turned out to be red.



**Figure 6.** Diffraction of the blue, green and red rays.

In the next step, the white light was used, obtaining a dispersion pattern as shown in Figure 7. The children appreciated that there is a continuous beam of colors, the center the light is white, and that the order of each color coincides in respect to the center, with what was seen and marked in the previous experiments.



**Figure 7.** Dispersion of white light through the CD.

To reinforce what was learned, the experiment was repeated with the white light and light beam of each color simultaneously on the screen as shown in Figs. 8, 9 and 10, for the children to confirm that each color of light coincided with the position in the continuous range seen in Figure 6.



**Figure 8.** Comparison of the white light scatter with the diffraction pattern of the red marker.



**Figure 9.** Comparison of the white light scatter with the diffraction pattern of the blue marker.



**Figure 10.** Comparison of the white light scatter with the diffraction pattern of the green marker.

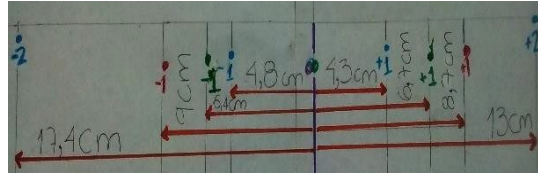
## 6. Discussion

The observations made in this section arise from the questions raised by the students during the practice and the operation of the materials used.

### 6.1. Apparent success of the experiment

The experiment achieved the plotted objective, since it allowed to show the phenomenon of dispersion by diffraction, evidencing that the position of each color is discreetly appreciated, but in fact belongs to a continuous band of colors and that each color is located in a different place according to its wavelength.

The following is an example by the students of measuring the position of each of the diffraction orders, for each wavelength.



**Figure 11.** Measurement of the position of the different diffraction orders for each wavelength used.

Students asked about the location of each color in a different place, which provided the perfect opportunity to introduce the concept of wavelength according to their cognitive ability.

## 6.2. Influence of materials

Performing this practice with the use of inexpensive and easily achieved materials, such as a piece of *CD*, laser pointers of different colors, white light lanterns, clay supports and screens with white sheets, the motivation on the children was high due to the simplicity of the experiment and easy acquisition of material. Naturally, safety precautions should be taken with the use of lasers by children.

## 6.3. The Methodology used

The realization of this practice with children using the *ALM*, in an intuitive way and with this type of materials, motivates the children in a great way the study of optics; an issue that should be taken advantage of by elementary school teachers in all schools in Colombia and later by secondary school.

## 7. Conclusions

The realization of this practice with children of young age, allowed to take advantage of the innate curiosity of them and the visibility that some optical experiments have. The objective was achieved by the children to understand the phenomenon of dispersion by diffraction, for discrete wavelengths and with white light, since they witness themselves the experimental evidence of the phenomenon. They were also to learn, through the answers to their curious questions, other elements such as: that white light contains the other colors, that there are discrete spectra and continuous spectra and that each color is associated with a wavelength. This shows a very positive result to which it is added that this type of experimental practices are within the reach of all socioeconomic levels due to the non use of specialized equipment and the use of materials of low cost and easy attainment.

## 8. References

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