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14 YEAR OLD STUDENT REPRESENTATIONS RELATED TO THE COLOR: A TEACHING INTERVENTION

Vu Hoang[i]
American Pacific University,
Vietnam

Abstract:
In this article is presented a research on the transformation of mental representations of 102 students 14 years old for the color in in a teaching context of optics. The empirical data were collected through an interview with an open discussion based on four tasks before and after a teaching intervention by a researcher to a small number of student groups. The research results show that the teaching intervention allow the cognitive progress of learners and are a suitable tool for systematic didactic intervention on the color.

Keywords: mental representations, color, secondary education, physics teaching

1. Introduction

Over the last 50 years, one of the basic research directions in science education concerned students' mental representations about physics concepts and physical phenomena (Bouzazi, 2019; Delclaux & Saltiel, 2013; Fragkiadaki & Ravanis, 2015; Nertivich, 2013). This occurred because educational psychology was accepted that children bring to class their own ideas about nature. This naïve knowledge is usually quite different from the knowledge from the scientifically literate citizen and the scientific models. In fact, everyday experience provides student with enough information to construct an intuitive understanding of many of optical phenomena. Teachers should know these spontaneous ideas with the purpose to try to modify them, in order to become compatible with scientific ones (Fragkiadaki & Ravanis, 2016; Nertivich, 2016; Syuhendri, 2017).

Among the concepts and phenomena whose study has yielded interesting results is the area of Optics. Relative research in the field of Optics elucidated many elements of the cognitive framework of students, before or after teaching, about light as an autonomous entity (Arnantonaki, 2016; Castro, 2013, 2019; Grigorovitch, 2015; Ravanis, 1999; Ravanis & Boilevin, 2009; Rodriguez & Castro, 2016), the rectilinear propagation of light (Castro, 2018; Guesne, 1985; Ravanis & Papamichaël, 1995), the shadow formation (Grigorovitch & Nertivich, 2017; Dedes & Ravanis, 2009; Voutsinos, 2013), the time of

[i] Correspondence: email vuhoang2020@hotmail.com

light propagation (Guesne, 1984; Ravanis & Kaliampos, 2019; Ravanis, 2019), the vision (Kokologiannaki & Ravanis, 2013; Sotirova, 2018).

However, a small number of research studies have been conducted to understand the color (Batts, 1999; Carvalho Jr., Carvalho, Silva Zacarias, & Oliveira Pinto, 2019; Chauvet, 1996; Feher & Rice Meyer, 1992; Keles & Demirel, 2010; Kocakülah, 2006). The most important results of these surveys show that the understanding of colors by the children is a result of a differentiation between shades of brightness and dark, the colors of the objects, just like the object's shape and texture, are taken to be properties of the object, a significant part of the misconceptions related to colors is associated with the effects of color of the light on objects. Also "*Some of the students have; 'the color of the light covers the objects' and 'the light can only illuminate the objects in the light's color' misconceptions. Some of the students explain the effect of light on objects with refraction and some others explain with the combination of the light's color and the object's color. Some other misconceptions are in relation with the illumination of an object with lights in different colors. Some of the students think the object will seem only in the color of the closest light source. Some others think that more than one source will cause the object seem white (even in two colors) and still some others think that it will form black color*" (Keles & Demirel, 2010, p. 3139).

The aim of this study was to approach the representations of 14-year-old students about color and their possible development after a specific teaching intervention.

2. Methodology

2.1. Subjects

The research sample included 102 students (52 boys and 50 girls) with an average age of 14 years and 1 month (S.D. 2 months), from 4 classes of three public secondary schools. The students were randomly sampled among those willing to cooperate. The students that took part in the research had not previously attended any organized teaching activity on the color.

2.2. The procedure

The research design for this research was quasi-experimental. It consisted of a comparison of the results of a pre-test and a post-test for one group, with which a teaching strategy were used to combat misconceptions about color. To explore students' representations about color, in a pre-test semi-structured individual interviews were carried out for about 20 minutes. While fixing the interview questions about the events on which students can do self-observation, some of the studies in the literature were benefited. After preparation, the questions were checked by three science education experts. Before the research process, needed modifications were made in accordance with their suggestions.

As for the study content, the following tasks were addressed to the students: Task 1. Which colors of light does a man have to illuminate in order to get white light? Task 2. If we illuminate a white page by a green light and blue light together, what color do we see? Task 3. If in a torch beam, we insert a red transparent filter, what would be the color of the beam falling on a wall? Task 4. If I illuminate a red apple with blue light what color will the apple be?

The final procedural step of our research consisted of a post-test. The same tasks were used in the post-test. The frequency values of these classified responses are presented in tables for each question in the results section. Under the correct answer in the first row, the tables show the answers that can be regarded as misconceptions and the answers that cannot be coded by researchers.

2.3. Teaching intervention

The teaching intervention, of approximately 30 minutes duration, was presented to groups of 6 to 8 children by a teacher-researcher. The context of the intervention encourages the individual involvement of each student, and facilitates the interaction among the students and between the researcher and the student.

The structure and content of the teaching intervention were as follows:

A. What is color and how do we perceive it?

The term color as used colloquially is often vague and full of misunderstandings. To get a clear picture of color requires a clear definition of the term. To help us reach this definition we must first analyze more closely the process of how we see color. An illuminated object reflects the light. This reflection is perceived and interpreted by the human. Exactly how the reflection is perceived depends on various aspects, on the one hand, the perception of light, dark and color and, on the other hand, the ensuing interpretation of the scenario. The purpose of this booklet is to give an insight into the perception of color and also into associated perception of light and dark. Generally speaking, this process can be divided into two areas: (a) from the light source to man and (b) the man.

B. From the light source to man

This area can be described fully in terms of physics. To do this we must first look at the term light more closely. In physics visible light is said to be composed of electromagnetic rays. Likewise, the rays emitted from radio and television are also electromagnetic. The electromagnetic rays of light differ for the rays carrying radio and television information only in their frequency. However, all we are required to understand at this stage is that light consists of electromagnetic rays within a certain frequency range. Seen from this point of view, an object is illuminated by rays of an electromagnetic source. The object reflects the rays to the man. The way in which these electromagnetic rays are reflected is partly responsible for the way in which color is perceived by man. The reflection is determined by the material properties of the object, whereby two factors are important: (a) The frequency of the electromagnetic rays reflected by the object. The object is illuminated with visible light from the entire frequency range. Which frequency range is reflected is determined both by the physical and chemical properties of the object and by the frequency ranges which are absorbed. (b) The strength of reflection of the reflected frequency range. Up to now, the term color has not been used in this section. This is because electromagnetic rays are colorless. They are described in terms of frequency. How electromagnetic rays are converted to give the impression of color is described in the following lesson.

C. Color and human eye

After the previous section was concerned solely with electromagnetic rays, we return to the subject of color. What in colloquial terms is referred to as the color of an object is, man's perception of the reflection of electromagnetic rays. These rays reflected by the reflecting object strike the man. The human eye converts the electromagnetic rays into information which can be understood by the human brain. The brain then interprets this information as a sensation of color. The eye is able to convert varying frequencies of electromagnetic rays into differing information for the brain. The brain interprets the differing frequencies-information as different colors. The eye is also able to convert the intensity of electromagnetic rays into information which the brain then interprets as a sensation of brightness. So, man is able to distinguish between changes in the quantity and the quality of electromagnetic rays and to interpret these as sensations of color and brightness. It is important to remember that all objects are colorless and that the sensation of color originates only in the human brain. This fact is extremely significant as it explains many of the effects connected with color.

Since it is the human eye and the human brain which are responsible for perceiving color, we shall look more closely at this system, its capabilities and how it functions. The human eye converts electromagnetic rays within the frequency range of visible light into information which the brain interprets as color sensations. The eye has special receivers for this purpose. Embedded in the eye's retina are the so-called staff cells and three different types of cone cells. The staff cells are responsible for vision which functions in very dim light and the cone cells are responsible for daylight and color vision. The retina contains approximately 120 million staff cells and 6.5 million cone cells. The three different types of cone cells differentiate in their capability to convert electromagnetic rays into information for the brain to process. They convert different wavelengths of electromagnetic rays. A typical human eye will respond to wavelengths from about 380 to 740 nanometers. In terms of frequency, this corresponds to a band in the vicinity of 430–770 THz. The sensation of red is allocated to the cone cell type with a maximum sensitivity of 620 nm. Green is allocated to the cone cell type with a maximum of sensitivity of 520 nm and blue with a maximum sensitivity of 450 nm. It therefore becomes evident that color is not a property of the body but a sense which is created as a result of electromagnetic rays of a particular wavelength striking the human eye.

D. The perception of color

Various things can influence our perception of color, e.g. the properties of the material and the composition of light and also the adjustment mechanisms in the human eye and the human brain. Our perception of color is naturally dependent on which wavelengths are reflected by an illuminated object. Equally important is the structure or composition of light. For example, if the light contains only the wavelength of approximately 620 nm, it is only possible for the color red to be perceived, assuming that the illuminated object is able to reflect wavelengths in this range. The proportion of red is at its highest in the morning whereas the proportion of blue increases towards evening. This may cause colors to be perceived differently. In this connection, the terms "conditional" and "constant" in relation to colors should be explained. Objects which only appear the same in a specific spectral light composition are referred to as "conditional" colors. Colors which always appear the same in all spectral light compositions are referred to as "constant" colors. This property is important, for example, in the case of car paints. If part of a car is resprayed at any time, it is important that the paint always creates the same impression of color regardless of what time of day the paint is applied. Car paints, therefore, must be constant colors. Spectral composition of light is also important when checking the color of clothes. Clothing creates different impressions of color when exposed to different conditions of illumination, e.g. daylight, artificial light. The color of clothing, therefore, should only be considered conditional. It is best to access the color of clothing in conditions of daylight where the impression of color is less likely to be influenced. Finally, just as a man is able to adapt to his environment the same applies to sight. Seeing and recognizing is essential if man is to survive in his surroundings. It is man's ability to adapt to his environment which is, therefore, important and not absolute sight, i.e. absolute color perception.

3. Results

Throughout the process, student's responses to the questions posed at pre- and post-test were recorded. Student's responses were classified into different categories. One type of response was compatible with the scientific model and others expressed some misconceptions.

Task 1: Which colors of light does a man have to illuminate in order to get white light?
In the first task student's responses and explanations fell into three categories.

Table 1: Categories and frequency of answers to task 1

	Pre-test	**Post-test**
When all colors of light are combined, white light is got.	7	72
When combined randomly two or more colors.	31	20
No answer.	64	10

It is clear that the students' progress is significant after the teaching intervention. The issue of the composition of light is important as it affects the understanding of a long series of phenomena.

Task 2: If we illuminate a white page by a green light and blue light together, what color do we see?

In the second task student's responses and explanations fell into four categories.

Table 2: Categories and frequency of answers to task 2

	Pre-test	Post-test
A mixture of two unique hues, appears.	19	75
White, because, when two or more colors are combined they yield white light.	55	17
Blue or green, because an object is seen as color of light close to it.	21	8
No answer.	7	2

And in the second Task as we see there is a significant improvement in students' representations as 55% move to the correct answers during the post-test.

Task 3: If in a torch beam, we insert a red transparent filter, what would be the color of the beam falling on a wall?

In the third task student's responses and explanations fell also into four categories.

Table 3: Categories and frequency of answers to task 3

	Pre-test	Post-test
Selective transmission of red light.	11	69
The red filter makes the color change.	35	14
The light is colored red in the filter.	35	13
No answer.	21	6

Here, while the pre-test is dominated by the representation whereby white light changes color, in the post-test the absorption by the red filter and the emission of the red color only.

Task 4: If I illuminate a red apple with blue light what color will the apple be?
In the fourth task, unusual for everyday life, in the students' answers we distinguished five categories.

Table 4: Categories and frequency of answers to task 4

	Pre-test	Post-test
The apple will have no color.	2	35
The red apple and blue light will give purple color.	52	28
The red apple will look blue.	14	17
The red apple will always be red.	21	18
No answer.	13	4

In the fourth task the result is difficult as it seems that the teaching intervention did not allow more than 32% to switch between pre-test and post-test.

4. Discussion

Our research of the knowledge acquisition in the domain of optics and especially of color have shown that student start by constructing a naïve understanding of the natural world which is based on their everyday experience.

The referred results may provoke appropriate discussion to open issues of optics education such as teaching strategies, curricula or teacher training (Galili & Hazan, 2000; Hoang, 2019; Krapaz, 1985; Ravanis, 2017). One of the more basic conclusions of the research is that students 14 years old do not differentiate the two fundamental concepts of the field: namely light and color. So, the students assign to the second concept features of the first. The case of non-differentiation of such concepts as light and color is not the only one, but seems to be included in a group of such pairs of relative concepts of physics. We can consider that temperature and heat, pressure and pressing force, density and mass are cases similar to the above.

The process of knowledge acquisition requires the rejection of these naïve mental representations and their replacement with a different explanatory framework. Finally, the results of our study lead us to question the organization of the optics curriculum of secondary schools.

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