WHAT THINKS THE UNIVERSITY'S STUDENTS ABOUT PROPAGATION OF LIGHT IN THE VACUUM?

Blizak Djanette
[1]Faculté des Sciences, Université UMBB, Boumerdès, ALGERIA
Chafiqi Fouad
ENS de Marrakech, Marrakech, MAROC.
Kendil Djamel
ENS de Kouba, ALGER, ALGERIA

Abstract

This study aims to study the conceptions of university students related to the notion of propagation of light in a vacuum. In order to fulfill our aim, a case study research method was used in the study, whose sample consisted of 321 Algerian undergraduates in different levels at science faculty (before and after the optics courses). The data were collected through a test comprising three questions. The results have indicated two students' misconceptions concerning propagation of light in vacuum. The first one is that the light does not propagate in a vacuum. The second is that the light propagates according the horizontal direction (new misconception). The possible origins of these misconceptions are discussed and suggestions for how to prevent them are given. Also, our results suggest that university students who had a higher level of physics knowledge than their counterparts who studied only geometrical optics, they still held of the same misconceptions. Formal or traditional teaching seems helpless to facing these misconceptions.

Keywords: Geometrical optics, Misconception and vacuum

Introduction

As Albert Einstein (1879-1955) said: "For the rest of my life I will reflect on what light is!"

Light is an essential feature of everyday life. It is used as a primary tool in many sciences (physics, biology, medicine, astronomy ....). Without understanding the concept of light and its properties, students should not understand many scientific domains. However, students find the subject of optics to be obscure and difficult and teachers help is often inadequate. (Galili and Hazan 2000).

Physics education research has shown that students have difficulties in learning optics. The topic of light is one in which many students have prevalent misconceptions. That's why the greatest number of studies is concerns "misconceptions" or "alternative frameworks," (students' ideas differ from those of physicists) in geometrical optics at the primary and secondary school. See for example (Guesne 1985, Fetherstonhaugh 1990, Galili et al 1993, Galili and Hazan 2000, Tao 2004, Outtara and Boudaone (2012). The Studies of post instruction students have revealed a persistence of student's misconceptions even after formal learning of optics (Goldberg and McDermott 1983). There exists important evidence on the fact that the students at the university often have the same conceptual difficulties and of reasoning about optics that those largely divided by younger pupils (McDermott et al 1996). Subsequently, Atwood and Christopher (2005) reported that a sample of elementary teachers also showed serious conceptual deficiencies for light concepts. Further, Gooding and Metz (2011) explained that parents, teachers, multimedia, and even learners themselves are responsible for fostering scientific misconceptions. Curricula and textbooks are also responsible for perpetuating misconceptions. Many teachers who knowingly, pass these inaccuracies on to students' misinformation that may never be challenged, or changed.

The impact of research on students' misconceptions about optics is impressive; the conceptual change is a recurring problem. Many misconceptions continue to appear among students and adults, and resist changing, even after receiving the necessary training. These misconceptions interfere with subsequent students' knowledge, conceptual change becomes very complex and, therefore, research efforts in this area would be quite useful.

So, for better learning and understanding of scientific concepts, it has been recommended that before the beginning of the instruction, the students' misconceptions should be taken into account by teachers (Picciarelli et al 1990 and Aydin 2012). Duit (2003) proposed that in order for learning to occur, students must first critically evaluate misconceptions and revise them to be compatible with the discipline. So, it's very important that teachers know more about student`s misconceptions in order to use the best teaching strategy to help their students construct a rich understanding of light concepts.

That's why a lot of data about students' misconceptions regarding the phenomena of optics have been accumulated, especially propagation of light. Some of these showed that many students believe that a medium is needed for the propagation of light, which is similar to the 'grip' of the ether that had many prominent scientists tethered to its aura for more than two centuries.

Although the propagation of light and the vacuum have attracted the attention of many scientists from antiquity to the present day, misconceptions of students about the propagation of light in a vacuum has rarely been discussed by sciences education researchers.

This study is focused about propagation of light in vacuum (region containing no matter; free space or empty) because this concept has never been treated before in science education research.

We begin with a discussion of the theoretical framework of our study. And, then we show our research questions, thereafter, we describe methods for collecting and analyzing data. Then, we present and discuss the results and conclude with final thoughts.

Alternative Conceptions about propagation of Light

Due to the property of light to travel from one point to another, Goldberg and McDermott (1986) established that the students at the university designs such as a luminous object which has a determined form, sends parallel rays. That the rays are parallel implies obligatorily that this is the privileged direction; it is generally a horizontal direction. Likewise, Galili *and Bendall* (1993) indicated that students often misinterpret the role of light rays in optical phenomena. They find that after instruction, students think that light emanates only in radial directions from the light source, with a preferred direction being toward the observer (they call this the "flashlight model"). As Galili points out, the "flashlight model" can be the source of many reported student difficulties in unique settings (such as pinholes, lenses, mirrors, etc.) and more advanced settings.

Shadows are formed when rays of light are stopped by objects, but students think that shadows can be conceived as an image, or as something belonging to an object (Anderson B, Bach F; 2005). There is a need to see light as an entity in space for being able to give an explanation of the formation of shadows (Galili and Hazan 2000). As well, students from Science Education department have low understanding abilities and many misconceptions about propagation of light. They did not distinguish light ray and light beam (Perales Palacios et al 1989). Also, Viennot (1996) shown that students at first year university do not understand the basic principle of image formation. She confirms that students' difficulty with imagery problem persists after secondary school. In addition, Kaewkhong et al. (2010), indicates Thai students, even after instruction, had significant misconceptions about the direction of propagation of light, how light refracts at an interface, and how to use a ray diagram to determine the position of image.

In previous work, we have shown the Algerian students' misconceptions about propagation of light, in university level. We proposed to 246 students in first year at university (aged 18–21) in Algeria closed and open questions (Blizak et al, 2009). The results show that these students have the same misconceptions, related to the propagation of the light in normal condition as the students in other countries (Andersson, Şahin, Galili, Goldberg, Viennot,…).

In their study, Reiner (1992) investigated students' ideas about light through group interviews of high school students. He identified that the students thought the nature of light was a stream of particles such as photons, while some students thought light was wave.

Also, Linder and Erickson (1989) found that students who had studies wave physics and sound, have great difficulties understanding the propagation of sound waves through air involve the incorrect descriptions of the motion of air or air molecules to account for sound. Moreover, Langley et al *(1997)* conducted research that showed that while students have some familiarity with optical systems, they were confused by a unified model of optics when the context of sight was discussed.

Subsequently, Ambrose et al (1999) studied the students' understandings of some wave phenomena of light. They found that students had difficulty knowing whether to apply geometric or wave optics. Most students do not develop a reasonable wave model for the propagation of light. And, after studying the photon, in advanced topics in physics, instead of correcting the way they think about the model of light, many students incorporate the new concepts they are learning into their defective model. It seems that the students, who think the amplitude of the light as a spatial quantity, think photons moving along sinusoidal paths when they learn about the particle nature of light. They use of a hybrid model with elements of geometrical and physical optics. Students can believe in contradictory theories and even merge them (Gilbert et al 1982). Hubber (2006) has reported that Students often misinterpret the role of light rays in optical phenomena. Students have not developed a consistent descriptive and explanatory model of light propagation.

In his study of the propagation of waves, Maurines (2003) showed that students (380 students aged 20 to 23 years) have a tendency to materialize the concepts (mechanistic reasoning). For these students, the concept of the light ray is similar to that of the trajectory of particles.

Thus, understanding the two main scientific models light, namely the models of waves and particles is not easy. The wave model teaches at physical optics, describes the propagation light energy similar to ocean waves moving in the water. The particle model of light that students learn in quantum mechanics explains light as a small quantity of energy called photons. In addition to these two scientific models, the ray model could be considered much more as the teaching model widely use in optics teaching.

The history of light propagation

By the history of science, we know that he had long discussions among scientists on this subject. The question that often been asked is: what is the most suitable model to explain the light propagation?

Thus, for Descartes (1596-1650), the light is resulting from friction between ether vortices propagates with infinite speed.

Isaac Newton (1642-1727) According to his corpuscular theory, the luminous bodies emits light particles (corpuscles) must necessarily travel in a straight lines with high-speed and in all directions in space and be governed by his first law of motion. Euler opposes to the particle theory of light of Newton and considers light as vibrations of the ether. For what concerns the propagation of light in ether, it made a similar manner to the propagation of sound through the air (Oon and Subramaniam, 2009). Fresnel (1788-1827) is whoever established that the vibrations of the ether must be perpendicular to the light.

In contrast, Huygens (1629-1695) believed that the universe is full of particles whose oscillatory movements are transmitted closer and closer. He introduced the term "Wave" and established a resemblance between sound and light. The wave theory have never explained how casting shadows by light.

Thereafter Thomas Young (1773-1829) conducted experiments that supported Huygens's wave theory. He used the analogy between the light and sound to establish the principle of superposition of light waves, but how the light travels through a vacuum remained a mystery (Rosmorduc 1987).

The history of science has also revealed a very impressive epistemological discussion on the existence of vacuum. The scientific community was divided between those who think that full vacuum does not exist (Al-Farabi (872-950), René Descartes (1596 -1650) and Willis *Lamb* (1913–2008) and those who supported the idea of the existence of the vacuum like Ibn-al-Haytham (965-1039) and Aristotle (384 BC – 322 BC). Thus, in the era of classical physics the vacuum is the region where the macroscopic material is removed, but modern physics has changed that quite a lot; there are virtual particles arising spontaneously in empty space (Rafelski and Muller 1985).

Research Questions

We believe that, given the different teaching strategies applied today, new misconceptions in optics subject can be revealed. We believe that the use of multiple models (ray, wave and particles) separated in the teaching of optics, without explaining their limit of validity, is responsible for students' misconceptions about the propagation of light.

Therefore, the research questions that this study sought to answer were:

- What thinks the students about propagation of light in vacuum at different university`s level?
- `Why students at the university have misconception about propagation of light in vacuum?

Methodology

To find an answer to our research questions, a research method case study was used in our study because it is suitable for including in-depth research.

Population

The participants in the study consisted of a total of 384 students at Boumerdes university in science faculty (age from 18 to 26). All of them had studied geometrical optics (GO) in the middle school. In Algeria, The mechanical wave (MW) and physical optics (PO) are taught at the University in physics department at different levels. In our university, only the SNV students learn geometrical optics. The following table shows the distribution of our population. Our discussion with the students, before the test, allows us to know that they have not studied GO and PO at high school, just some notions about optics, in middle school.

Table 1. Distribution of students in this study.

Group	Number of students	Level	Instruction	Date of test
L0	246	First-year undergraduates (SM[a], ST[b] and SNV[c])	GO at middle school	At the beginning of the first semester (2009-2010)
L1	78	First-year undergraduates (SNV[c])	GO at university	At the end of the second semester (2011-2012).
L2	24	Tthird-year undergraduates (physics)	MW, PO and QM	At the end of the second semester (2011-2012)

[a] Materials Science
[b] Technical Sciences
[c] Life Science and Nature (Biology)

Instrumentation

From a survey of literature, it is found that most works on conceptions and misconceptions about optics have employed interviews and/or open-ended questionnaires. Little research has used multiple choice tests. In our work, the paper multiple choice test was chosen as most appropriate for investigating a big sample of 246 or 78 students. We also use open-ended questionnaire for shorts groups of 24 students. The test was taken by the students in a regular class environment, under the condition of no time limit and was assessed in

French language. Also, the students were confirmed that the results of the test would be used for research purposes and would be kept confidential.

In order to identify university students' light misconceptions, we asked students of L0 group (246 students) to answer some questions (multiple choice test) which had been used in previous studies of the light preconception (where their validity and effectiveness had been proved). The students in this group have just entered the university. The same questions are asked of students in the group L1 (78 students) in order to know if there was or not any conceptual change after a formal teaching of geometrical optics. We recall that this group of students has completed the course of geometric optics during the first year of university (see table 1).

For the L2 group, we asked students to justify their answers. During their university studies, these students have studied the mechanical wave (MW), the physical optics (PO) and Quantum mechanics (QM).

Our questionnaire comprised three questions about propagation of light in vacuum (see table 2), which are selected and partially modified from the studies investigating students' conception (Fetherstonhaugh (1990), Goldberg and McDermott (1983), Chung-chih Chen (2002), Blizak et al (2009).

Table2. Questionnaire description.

Question	Description
Q1	Using camera obscura (Figure 1)
Q2	Obstacle between source of light and screen (Figure 3)
Q3	Formation of the image using a convergent lens (Figure 5)

Results

In this section, we present the students' responses to each question (Q 1, Q 2 and Q 3).

*Camera obscura (***Q 1***)*

In the following situation, we showed the ordinary case where air exists (Figure-1), and we asked students of groups L0 (264 students) and L1 (78 students) to choose the answer that show what will happen on the wall opposite the hole if there is a vacuum (no air) inside the camera obscura. The answers to this question are in table 3 and figure 2.

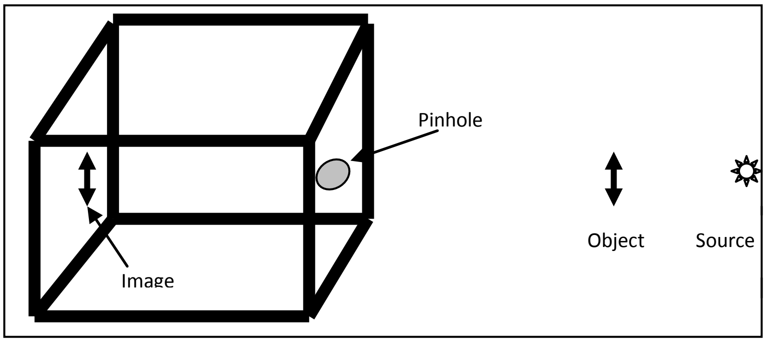

Figure 1. Camera obscura

Table 3. The distribution of students' responses to the question 1.

Answer	L0 N=264	L1 N=78	L2 N=24
No change	**27%**	**29%**	**42%**
The image disappears	**44%**	**51%**	**33%**
Appear a spot of light	**21%**	**17%**	**25%**
No answer	**8%**	**3%**	**0%**

Before any optics course at university, only 27% of asked students (L0) , give a good answer. But almost half of the questioned students (44%)) believe that the air is necessary for propagation of light and without air there is no image.

Significant numbers of students (21%) before any instruction about GO at university, thought that light propagates in only one direction (horizontal) under the conditions where the vacuum exists.

In addition, the result shows that after the course of GO, the students' concepts about propagation of light in vacuum have not changed. More than 50% of students of L1 group think that the propagation of light requires the existence of a medium.

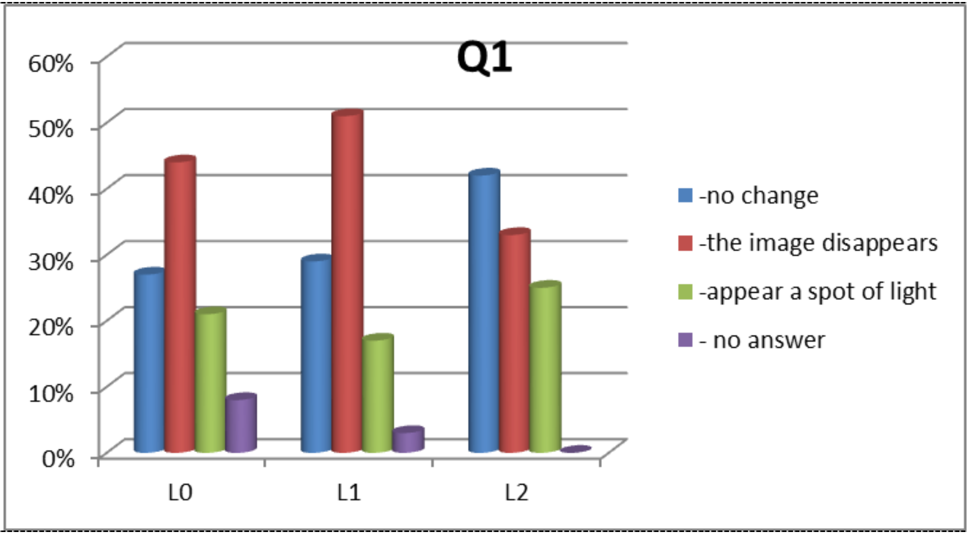

Figure 2. Histogram shows students' responses to Question 1.

In order to know more about students' ideas in this subject (the propagation of light in a vacuum), we asked students of L2 group to justify their answers. We show in table 4 the explanations given by some student.

Table 6. The explications given by students of L2 group to justify their answers (translated from French to English).

Student	Students answer	Students` explications
1	No change	-The air has no influence on light propagation.
2	\\	-Because the air has the same refractive index as the vacuum.
3	\\	-If there is a vacuum the image becomes sharper because when there is the air there is friction.
4	The image disappears	-We need a medium which propagates the light.
5	\\	-The particles of the air make the visible light.
6	\\	-Vacuum absorbs all the light like a black hole.
7	Appear a spot of light	-In the vacuum there is no diffusion of light in different directions. The light passes directly.
8	\\	-In case of vacuum, the light wave would choose only one direction.

***Shadow* (Q 2)**

In this situation, we showed the ordinary case where air exists (figure-3), and we asked students of groups L1 (78 students) and L2 (24 students) what will appear in the screen if there is a vacuum inside.

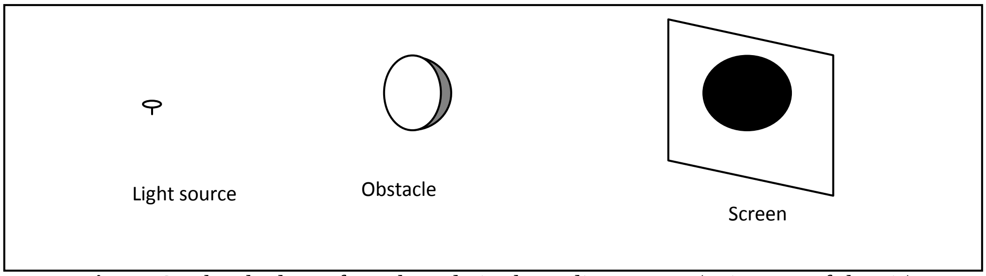

Figure 3. The shadow of an obstacle in the ordinary case (existence of the air).

The results extracted from the question 2 (Q 2) have the similarities to findings that we have shown above (figure 4). We note that a very small percentage of students in both groups (L1 and L2) believe they have a spot of light on the screen (in the case of vacuum). For more than 50% of the L1 group and more than 40% of L2 group there will be no image. These percentages include both students who believe in the horizontal propagation of light and those who believe that the light does not travel in a vacuum (See figure 4).

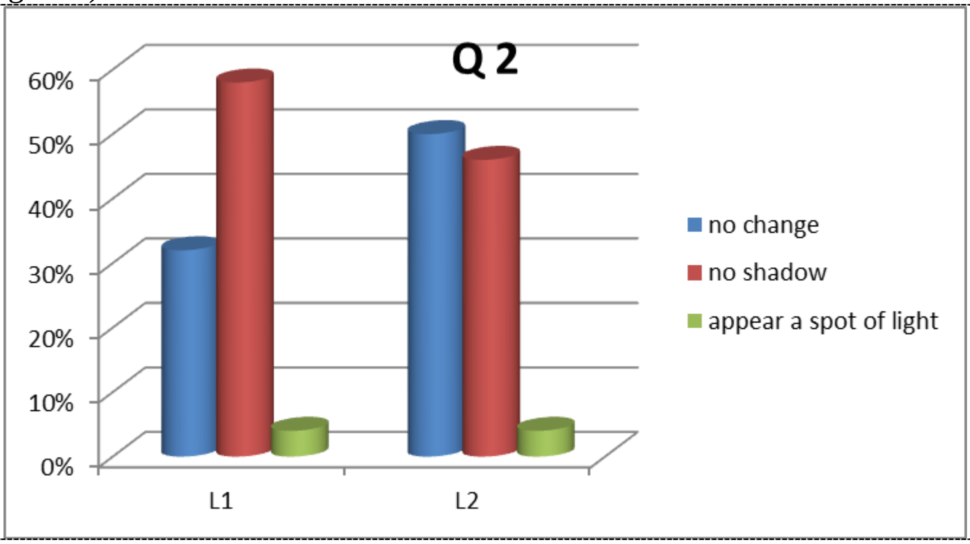

Figure 4. Histogram shows students' responses to Question 2.

***Forming of the image with a thin lens* (Q 3)**

For that question, we have shown the case of the figure 5, and we asked the students in groups L1 and L2 to tell what will appear on the screen if there is a vacuum inside.

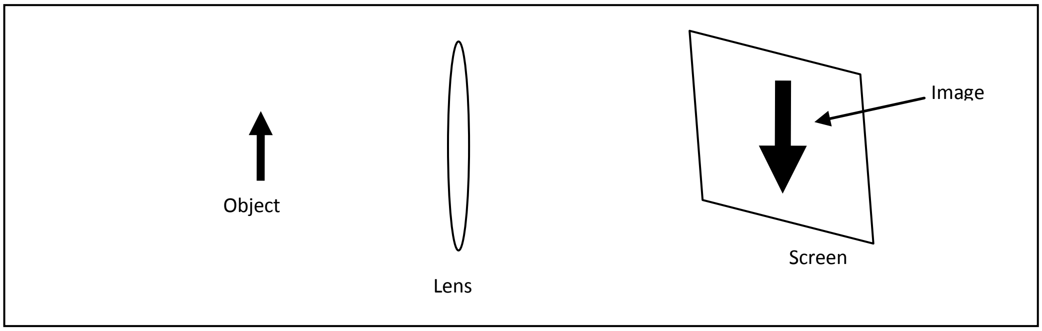

Figure 5. Formation of the image in the ordinary case (existence of the air)

Of the histogram that shows the students' answers to the question 3 (Q 3), we notice that the same peoples of both groups, who gave a correct answer to the question1, have not changed their opinion in this case (figure 6). But students, who think of the horizontal propagation of light in a vacuum, are now shared between two answers: right image and spot of light.

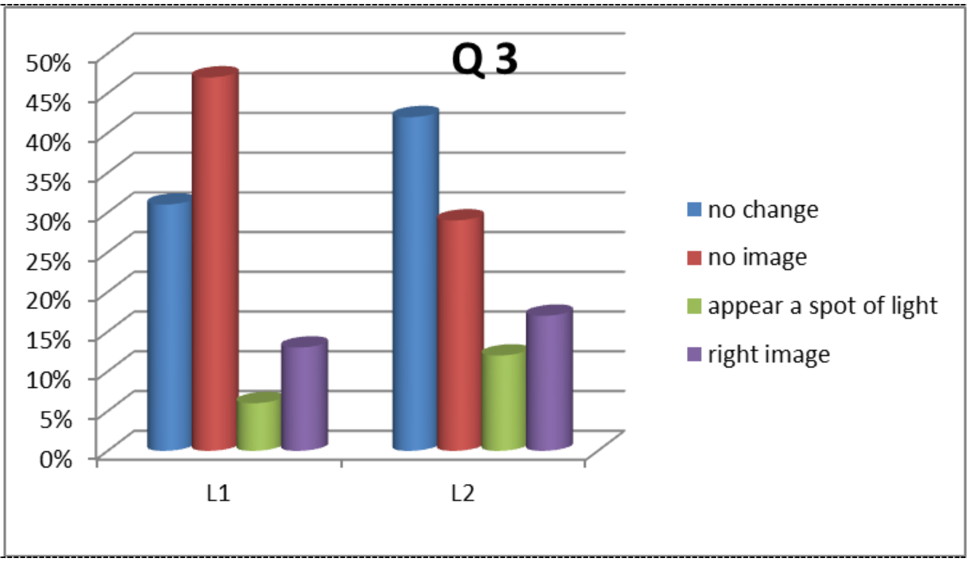

Figure 6. Histogram shows students' responses to question 3.

Discussion

We find that many of the students in different levels of university studies and different options believe that light does not propagate in a vacuum. This result was expected for the students who have just entered to the University (L0 group). Sexena (1991), in its research to identify the Indian students' conceptions in optics (16 are 20 years old), affirms that for many subjects the light cannot penetrate in a completely empty room (vacuum).

Some studies assert that the number of students, who presented misconceptions before teaching, decreases after instruction. But in regard to the propagation of light in a vacuum we find that a large percentage (51%) of students who have taken courses on geometric optics (L1 group) still think that light do not travel in a vacuum (figure 2). The most interesting misconception that we have found is that some students think; in vacuum, the light propagates according to the horizontal direction. We have not been able to find this misconception in the literature. But, the "Flashlight model" that has been highlighted by Galili (1993) could be the cause of this misconception.

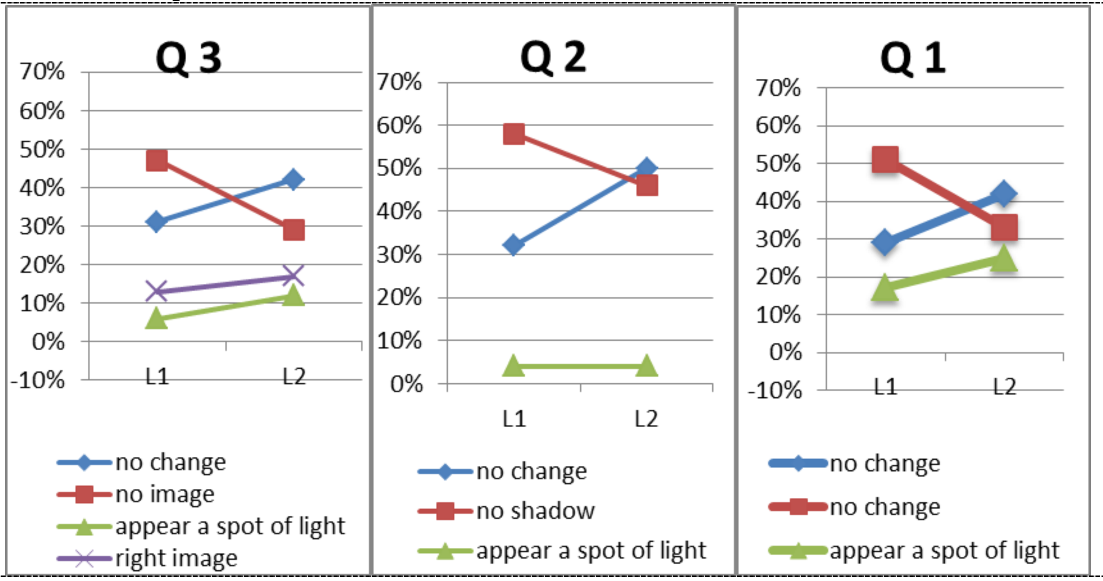

Figure 7. Comparison of the responses of students in the two (L1 and L2) groups for the three questions (Q-1, Q-2 and Q-3).

To make a comparison between the results of L1 and L2 groups, we drew the graph of figure 7. As we can see, a large percentage (more than 40%) of students who have not studied GO (L2), have given a good answer for the tree questions (Q1, Q2 and Q3). By the contrary, more than half of the students who have studied GO believe that the image disappeared when the air does not exist.

In the course of GO (also manuals), we find the following expressions:

- The light ray (the light) passes from one medium to another;
- The light propagates in a transparent medium;
- The more refractive medium is air;

- The refractive index of medium is n;
- The velocity of light in medium is ....

As we see the vacuum word, which means a space entirely devoid of matter (oxford dictionary 2011), is rarely used to explain the propagation of light, whether by the teachers or in the manuals. For us it is very clear. This explains that reason why a large number of students of L1 group have primitive ideas about propagation of light in vacuum after a formal education.

As well, the students of L2 group are familiar with the use of the vacuum word. They studied MW and PO (mechanical wave and optical wave). This explains why a significant number (42%) have given a correct answer, despite that they have not studied GO.

Our reasoning is justified by the explanation given by some students of L2 group, as it is shown in the table 4. Note here that the students seem to materialize concepts (Maurines 2003).

For many students (figures 2, figure 4 and figure 6), an air or medium is necessary for the light propagation or for that the light to be visible. This result has the similarity to the findings of Yalcin (2008), when he identify first year Turkish science undergraduates' misconceptions and misunderstandings of light concept and its propagation. They believe that the medium is a kind of support that allow light to travel through medium. Also, the history of science reveals that many scientists have made an analogy between sound and light for understanding the optical phenomena.

Also, it happens that among students that we have analyzed their answers, who thinks that the vacuum is like black hole that absorbs all light. The existence or not of the vacuum was and still the subject of an epistemological discussion between the scientists.

As we see in table3 and all figures, these misconceptions resist to changing, even after learning the geometrical optics or physical optics, which concord with the results of Posner (1982) and Sahin (2008). They have found that misconceptions are fairly resistant to change by conventional teaching strategies.

We thought at the beginning that the new misconception that we have found among certain members of L1 and L0 groups will disappear among students who made deeper studies in physics. After the analysis of our data, we discover that quite a number of students in the L2 group; also, believe that the light propagates in horizontal line. So, the most amazing thing that we found is that the upper level students (in advanced topic in physics) believe that the particles in the medium are responsible for the propagation of light in all directions.

The justifications that are given by students are not sufficient to explain the origin of the misconceptions. The students discuss about the diffusion of light rays in all directions when the particles of the air exist. It seems that these students could not choose the correct light models to explain light propagation and did not have a functional understanding of wave and particle theories of light. Also, we think that one of the reasons that blocks conceptual change on the propagation of light and vacuum, in some third-year undergraduates, it is their misunderstandings in modern physics topics.

We believe that students used various concept models to explain how the object can be seen. It is the same result that was confirmed by Hubber (2006). He found that students could not choose the correct light models to explain various light phenomena. We believe that further research in this direction is important.

Conclusion

▪ After nearly 30 years of research on students' misconceptions about the phenomena of light and optics, this study showed that there are still misconceptions which can be detected and be a subject in-depth study. We can summarise our results as follows:

- the students in different levels of university studies and different options believe that light does not propagate in a vacuum;
- many students who have taken courses on geometric optics still think that light does not travel in a vacuum;
- some students think that, in vacuum, the light propagates according to the horizontal direction (new misconception);
- the students who have studied the different types of waves and models of lights, also they have misunderstanding about propagation of light in vacuum.

For some studies, the use of a hybrid model of light (a photon must contain both wave and particle characteristics) by some of the students, do not allow them to get an understanding of scientific concepts in optics. According to Justi and Gilbert (2000), the introduction of the history of the development of scientific models and ideas into the teaching education is essential for the elimination of hybrid models and for a conceptual change in a good way. We note here that the majority of students who have misconceptions that have been shown in our results, they will, in the future, teachers in middle or high school. This might be the reason for the emergence of misconceptions among university students. They may have to be studied physics classes with teachers who have low levels of understanding of geometrical optics.

The university student's beliefs about a concept of propagation of light, even in vacuum, have to be revealed and made transparent. So the traditional instructional methods, which are focusing on reading and solving the problems, are ineffective in overcoming certain misconceptions. The teaching for conceptual change is more effective than traditional instruction.

As well, a teaching strategy based on the history of the concepts of the nature of light and its propagation can give good result. Also, tutorial intervention, in a conventional physics course, is a kind of instruction that can persuade students to think about the basics of the ray model and the propagation of light more profoundly (Kesonen 2013).

Lecturers, teacher and text writer must use the concept of “vacuum” when they give examples or when they discuss problems about the propagation of light. As well, they have to pay enough attentions to qualitative reasoning, or understanding of what is meant by a physical explanation and warn students about details, which can be misunderstood.

I wish to conclude by saying that further investigation would be required to see what teaching strategies are most effective in helping students develop more appropriate reasoning in this area.

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