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Determination of university students' misconceptions about light using concept maps

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Abstract

The concept map has evolved, in recent years, as an important teaching and learning tool. It engages students in active learning and assists instructors with their delivery. Thus, we believe that it has the power to be relevant and effective to reflect the design of a poly-functional teaching tool. We argue in favor of renewing didactic tools used in education, in general, and in teaching GO (geometric optics) in particular. The main purpose of this study, however, is to show that the concept mapping is a very effective way in terms of revealing the misconceptions of students, studying GO, during their university year. 52 freshman students (first year) majoring in life science and nature (LSN) were asked to draw a conceptual map about propagation of light; a two-stage experiment: before and after formal teaching sessions. The findings of the qualitative analysis of the students' maps are in line with the results of other research; students have many misconceptions about light and traditional strategy used for teaching GO is not effective for conceptual change. Also, The approach of scoring tasks, as only one survey is not recommended.

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*Keywords:*misconception; conceptual map; light.

1. Introduction

Last two decades Opticsand its application have seen a tremendous developmentin various fields ofscience. It has been an interesting research area for researchers inphysics education, because, without understanding very well the fundamental concepts of lightand its properties, students are not expected to fully grasp modern science. That's why; student's misconceptions ('preconceptions', 'alternative 'frameworks' or 'intuitive notions') about light in different countries have been investigated.

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Many scientists in science education have established thatGO is one of the topics where students' have many misconceptions (Goldberg & McDermott, 1983; Guesne, 1985; Fetherstonhaugh, 1990; Galili &Bendall, 1993; Galili & Hazan, 2000; Atwood & Christopher, 2005; Blizak, Chafiqi & Kandil., 2009; Outtara &Boudaone, 2012).

Students were found not to be able to explain light related phenomena in scientific language, despite their knowledge about them. (Uzun, Alev,&Karal, 2013)In addition, studies have revealed resistance to efforts directed toward changing student's misconceptions even after a formal learning of optics (Goldberg & McDermott, 1983).However, although their conceptionsare scientifically wrong, it contributes to their understanding of the natural phenomenon (Eryılmaz&Sürmeli, 2002). Also the stronger their misconceptions are, the more resistant to change they are which creates a conceptual barrier that limits or prevents learning from happening. Misconceptions must be addressed because they may have a negative effect on the process of learning.It has been recommended that before the beginning of the instruction, students' misconceptions should be taken into account by teachers (Smith,diSessa &Roschelle, 1993; Aydin, 2012). So teachers or researchers must be interested to take into consideration the misconceptions about light to implement an effective teaching strategy that helps their students develop a correct understanding of light concepts.That's why a lot of data about students' misconceptions regarding the phenomena of optics have been accumulated (Blizak, Chafiqi&Kandil, 2009).

The most methods commonly, usedin education to identify students' misconceptions include interviews, Open-ended questions, two-tiered multiple choice tests and multiple choice tests. A concept map is being more used as a teaching tool and a tool for summative assessment of students' performance. It has been considered as renovating and efficacy research instrument that can inform investigators about students' misconceptions about a particular subject, rather than solving a questionnaire that contains paragraphs sometimes, without interest, followed by a random response without sense. This technique was introduced and developed by Novak (Novak, 1979) to facilitate the organization of knowledge as a hierarchical structurein a specific field. It builds on the science of constructivism. Concept maps visualized through a graphical representation are commonly defined as two dimensional diagrams that consist of concepts or nodes (put into an ellipse, circle, rectangle or square) jointed by labelled lines (the words or phrase) to show relationships (propositions) and interrelationships between those selected concepts. Two concepts connected by linking words indicating the relationship between the concepts form a proposition (Novak, 2006). The map can be in the form hierarchical, cluster or chain form.

The concept mapping can promote meaningful learning, provide additional resource for learning, allow instructors to provide feedback to students and evaluate learning and performance (Daley & Torre, 2010). Concept maps are a visual representation of how a student sees the relationship among different concepts; they can also serve as useful tools for describing the student's conception in a specific field. Because they are a window on the brain,theyidentifysomeepistemological obstacles (Paquette, 2002). Also, other researchers (Wallace &Mintzes, 1990) showed that concept maps are valid and useful methods for detecting conceptual changes. Concept mapping has also been used as a tool to reveal students' misconceptions (Langlois, Raulin&Chastrette, 1994). Misconceptions are identified as incorrect propositions and/or missing or faulty links between two or more concepts. A quantitative approach can be used, in addition to a qualitative analysis, to analyze concept mapping and evaluation. Combinations of scoring methods such as the number of valid links, the degree of cross-connections among concepts, measures of branching and hierarchical structure (Dorough&Rye, 1997) support the quantitative analysis. However, these measures have limitations because 'invalid links' that are often the most informative are not taken into consideration. There have been relatively few studies that have used concept mapping to identify students' misconceptions at a university level and, to our knowledge; no study has been in the field of the GO. Therefore, the purpose of this study is to attempt to address this gap. The intent is to identify Freshman University students' misconceptions about propagation of light (GO) using concept mapping before and after instruction.The following sectionspresent the research questions, the research method, and results and discussion. The paper concludes with the final thoughts.

2. Rationale

As stated above, various research studies have been conducted about student`s misconception in GO. The scientists have used an interview questionnaire or multi-choose questionnaire to explore students' misconceptions about vision, propagation of light, image formation, refraction, and reflection. We believe that these two methods are very useful but sometimes, the student chose the wrong answer not because of misconceptions, but because of the lack information or knowledge or because the interviewersdisorientstudents in theiranswers. The purpose of the present study is to show that the concept mapping is a very effective way to reveal the misconceptions of students in the first university year in the case of the propagation of light before and after formal teaching. By the same token, we to confirm that the traditional teaching is ineffective for conceptual change in this case. Therefore, in this study willattempt to answer to the followingresearch questions:

- Using concept mapping, what are the misconceptions, before and after instruction, about light propagation, of students in their first university year?
- Is the traditional teaching method effective for teaching light?Equations

3. Method

A case study research was chosen for this study to investigate the students' conceptions about light.

3.1. Population

For this pilot study, the data were collected from 52 students studying at the faculty of sciences (Department of Biology) in Boumerdes University (in Algeria). The sample was composed of 48 female and 4 male students whose mean age was 19.07 years. All of them had studied geometrical optics (GO) in the middle school.

3.2. Procedure

The study has been implemented during the second semester of the academic year 2012 / 2013 in a regular class environment. Initially, students participating in this study were trained in concept mapping technique with practice exercises in the mechanical and electricity topics. Consequently, students have been familiar with concept mapping.

Before starting the course of geometrical optics, students were given a set of 11 concepts and asked to create their own concept maps to respond to the question "what do you know about propagation of light", under the condition of no time limit. The researchers informed the participants that they are not obliged to use all the concepts in the list and that they could also integrate any other concept that they believed was relevant to the question asked. We leave the student free in his choice of links. Also, the students were free in their choice of language (French or Arabic). As the classroom was regular they drew their concept maps with pen or pencil.

After two weeks, students enrolled in courses about light (OG) taught in a traditional way (According to traditional teaching strategies). Courses lasted for four weeks (six hours of lectures and six hours of tutorials). Two weeks after the course, students were invited again to establish a new conceptual map about propagation of light by following the same instructions as the first time.Concept maps drawn by students were then analyzed qualitatively to identify students' misconceptions and quantitativelyto reveal the development ofstudents' learning processes.

There are several concept mapping scoring systems.For instance, some studies used Novak and Gowin scoring methods (Novak &Gowin, 1984). They utilize four criteria; valid propositions, valid level of hierarchy, valid cross-linking, and examples. In this study, the authors decided to use the relational scoring method which can yield the most reliable scores and simple technique (McClure, Sonak&Suen, 1999).The propositions identified on the map were scored from zero to three based on the following scoring protocol:

Zero is assigned to invalid links that were constructed based on incorrect scientific information. One is assigned to the link that connects interrelated conceptsbut misses the label. Two is given to the link that is scientifically correct and has a possible label indicated but does not specify the direction. Three is given to the correctly labeled links with the specified directions. The final score for the map was determined by summing up all the scores. Thus, the collected 51 maps served as a basis for content analysis. One map was disregarded as incomplete. Statistical analysis was conducted using SPSS 19.0 package program.

4. Results

Thepre and post concept maps were examined one by one. We basically looked for invalid propositions and unlinked conceptions. This qualitative analysis indicated that the students before and after instruction have many misconceptions about propagation of light. Table 1 shows the relevant misconceptions and their occurrences in students' maps. We found out that students developed new misconceptions about propagation of light after instruction in GO, while some pre-maps misconceptions have disappeared in post-maps.

Table1. Qualitative analysis of students' concept maps.

Misconceptions	pre-maps		post-map	
	frequency	Percentage	Frequency	Percentage
A shadow is a `reflection' (reproduction) as an image of the object.	3	5,7	2	3,8
Shadow can be produced by the mirror.	8	15,4	3	5,7
The object has a shadow or contains shadow.	2	3,8	3	5,7
There is relation between speed of light and shadow.	4	7,7	3	5,7
Light travels from the eyes to the object.	1	1,9	0	0
Light illumines the object and eyes see it.	3	5,7	0	0
Light travels to the eyes and eyes see the object or give an image.	16	30,7	10	19,2
Image arrives into eyes or eyes receives (captives) image.	2	3,8	1	1,9
Light can be reflected by the lens.	8	15,4	2	3,8
The source of light gives speed to the light or speed is depending on the source of light.	9	17,3	5	9.6
Speed of light has not relation with refraction or medium.	17	32,7	9	17,3
Eyes reflect the colors or gives color.	11	21,2	8	15,4
The colore is specific to the object or the object has color or contain color,	8	15,4	6	11.5
Mirror transferred image.	1	1,9	0	0
Light rays are passing through the centre of the lens.	0	0	3	5,7
Lens gives bigger image.	0	0	1	1,9

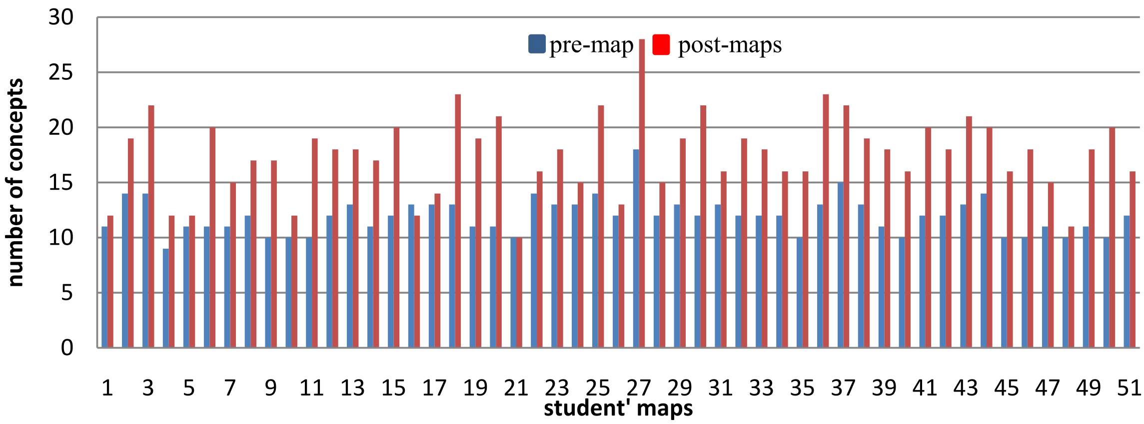

Fig. 1. number of concepts used in each student`s light maps (before and after instruction).

Students have used more concepts in the post-maps than in the pre-maps. Table 2 presents a summary of the maps score given by the relational scoring method.Statistical analyses showed that students' post-maps (M = 21,666; SD = 6,392) scored significantly higher (t = 11.316; p < 0.025) than students' pre-maps (M = 13,882.0; SD = 5,446).Students' concept maps that was used to draw information on misconceptions and scores show that the students used more concepts in the post-map that they had correctly linked to form new valid propositions. But students` misconceptions are the same in both maps.

Table2. Mean and t-test for score in students maps

	N	Mean	SD	df	t	Sig. (P. value)
Pre-maps	51	13,884	5,446	50	-11,354	0,000
Post-maps	51	21,666	6,392			

5. Discussion

The main purpose of this study was to show that the concept mapping is an effective way to reveal the misconceptions of students, about light propagation, in their first university year. To address the first research question, 16 misconceptions were identified which occurred several times in the collected maps. Students' misconceptions are listed in table. 1. along with their respective percentages and frequency of occurrences. Students'perceptions is that "light travels to the eyes and then the light is reflected to an object, so the object can be seen" Another crucial misconception or vague explanation was that "light travels from a light source to an object and eyes see the object". Not all students in both maps were able to provide a clear and scientific explanation of the sight process. They neglected the light reflected from the object reaching the eyes. These misconceptions about sight have been revealed in many physics education studies. Also, Winer et al (2002) affirmed that the belief that the process of vision includes emanations from the eyes was originally professed by early Greek philosophers and which persisted in scholarly circles for centuries.

Furthermore, the maps show that students have misunderstandings about light refraction. They think that "speed of light has not relation with mediums", "the source of light gives the speed to the light rays". This is similar to findings in literature where misunderstandings are "speed of light has the same value in all medium "(Anderson and Smith, 1986). Also, some students think that "colors are as a property of objects" and "eyes give colors to the object or reflected colors to the object".

It's clear for us, that students in the first level at the university do not understand very well the straight-light propagation of light. They believe that "a shadow is something that exists into objet" and "the shadow can be formed like image". This result is in agreement with research of Feher & Rice (1988); they showed that students believe that the shadow is tied at the objet and that the object thrown out something that exists in it.

So, since the students have misconceptions about sight, refraction and the rectilinear propagation of the light, they have also, misunderstanding about image formation by lens and mirror. This result was also compatible with the results of Viennot (1996) indicating that student's difficulty with imagery problem persists after secondary school.

More misconceptions about propagation of light were presented in previous works (Blizak, Chafiqi& Kandil., 2009), where we have used a multiple choice test. But conceptual map has allowed us to know other misconceptions like "the speed of light has a relationship with source of light and none link with medium".

The researchers in science education have pointed out many reasons for these misconceptions. Eshach (2003) pointed out that many linguistic constructions such as "we throw a glance" or "give a look" did not conform to the scientific knowledge about sight. Viennot (1996) pointed out that the difficulty of first year university students is with the materialization of the light ray. Worthy (1987) also confirms that some textbooks contribute their part to the formation and persistence of misconceptions.

Then, our results in table.1, show that students Misconceptions of light propagation are very resistant to traditional instruction (McDermott &Redish, 1999; Pfundt &Duit, 1994; Guesne, 1985);only few students were successful in changing these misconceptions.

A quantitative approach was used to address the second research question. Fig. 1 indicates that the number of concepts used by most students in pre-maps is in the region of 11 concepts (in instruction we have given 11 concepts) but after 2 weeks after instructions students used more concepts. It seems that students have been able to recall information from their lessons and tutorial session on GO.

As a result, this augmentation may have an effect in scoring maps. The mean score mapping has increased from 13,88 in pre-maps to 21,66 in post- maps. Even, if there were statistically significant differences between the mean scores of students' maps in pre-maps and post-maps in favor of post-maps ($t=11,354$; $p < 0.025$), this result just means that students have remembered more knowledge relate to the propagations of light. We can see in figure 2 that student in his post-maps, use equations, example and give more propositions about refractions and reflection. This has increased the score from 19 (pre-map) to 28 (post-map). But the student still has misconceptions. It should be noted that the high score of conceptual map does not mean that the student has fewer misconceptions.It means onlythat the student hasmoreknowledge (number of conceptshas increased) because the missing links and invalid propositions have not been taken into account of quantitative scoring concepts maps methods. The invalid links in a student's map may reveal much about the thought processes that lead a student along a particular path of understanding (Hay&Kinchin, 2000).

Our quantitative results are not consistent with the researches in science education which have confirmedon several occasions that the traditional teaching, which is widely used in our universities, is not effective for the conceptual change especially in the case of GO.The relational scoring method (McClure, Sonak, &Suen, 1999) whichscores only the valid proposition and missing the unlinked conceptions or invalid proposition is not in accord with the process of learning and constructivist philosophy.

VonAufschnaiter(2006) is in accord with us. He argues that the quality of understanding of the concepts usedby the studentsis more important than their amount or accuracy.

So, the qualitative analysis of concept maps is more appropriate than quantitative analysis if the aim is to reveal students' understanding as it relates to a specific field (BakKibar, Yaman&Alipas-aAyasc, 2013). Furthermore, research indicates that alternative conceptions of GO are highly resistant to change even in the face of formal instruction and present a significant obstacle to achieve accurate understandings of related concepts(Galili&Hazan, 2000 &Viennot, 1996). The teacher in formal teaching considers that the students are passive receivers of knowledge, and uses techniques that place undue emphasis on memorization of information and algorithmic problem solving. Instead of using traditional teaching methods, the teaching can be performed by using different methods for conceptual change (Sarıoğlan&Küçüköze, 2014).

6. Conclusion

Many researchers around the world have been studying misconceptions about light for the last 40 years. It was clear from their findings that light has a difficult concept to understand, and these misconceptions have a negative impact on student learning. For this reason, it is agreed that it is necessary to investigate students` misconception before application of a teaching strategy based on the conceptual change. Most researchers have used tired multiple choice test and interviews, but rarely concept mapping to investigate students` misconception.

By using concept mapping, our analysis, confirmed earlier research indicating that students at introductory university level have many misconceptions about propagation of light, which resist change after traditional teaching.

The qualitative analysis of students' concept maps has revealed other misconceptions which have not been noted in our previous study by using multiple-choose test. Some of these are as follows:

- "the source of light gives the speed to the light rays";
- "coloris as a property of object" ;
- "eyes gives color to the object";
- "shadow is something that exists into object".

Also, we noted a significant difference between the scores of maps before and after instruction in favour of the traditional teaching. However, students still have misconceptions after traditional teaching even their scores, by using the relational scoring method, have increased. Therefore, the approach quantitative by scoring methods, as only one survey is not recommended. An in-depth analysis of the concept map would be more effective.

In light of the findings of this study, Concept mapping is able to reveal students` misconceptions related to the light. So, we suggest that teachers and researchers in science education should use, asfrequently as possible, concept mapping as a research tool because it is easy to use and more reliable than conventional tests.

More research must be conducted to test concept mapping as a method to determine misconceptions with a larger number of students at different levels with different topics. Finally, we hopethat the resultsof this studybeusedin other studies.

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