

Students' Understanding of Light Concepts in the Secondary School

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Abstract

Learning science is a complex process and students develop limited understanding even after instruction. The aim of the research is to use students' diagrams to assess conceptual understanding of science related to 'light' in grade eight students. Data were collected with the use of a written test, questionnaire and documents. Each question of the written test consisted of two parts; diagram and written explanation. Data obtained were analysed qualitatively and quantitatively. It was noted that students provided more than twenty different diagrams for each question instead of correct diagram. A large number of incorrect diagrams with incorrect explanations showed that students did not possess a correct understanding of concepts related to light. Responses to teacher questionnaire revealed that 98% of teachers provide opportunities for their students to draw diagrams to assess understanding of science. Students' diagrams can be effectively used to assess conceptual understanding of science knowledge of secondary students.

1. Introduction

Science is a main subject in the school curriculum from grade six to grade eleven in Sri Lankan Education system. Science includes concepts related to physics, biology and chemistry and number of these concepts either concrete or abstracts and most of the concepts in physics are abstract in nature [7]. [4] emphasize that, majority of students come to science classes with knowledge or beliefs about the phenomena to be taught and many students develop only a limited understanding of science concepts after instruction.

Assessment is an essential part of instruction it enables teacher to improve teaching learning process. According to [2], monitoring and evaluating students' work both at the end of a lesson and throughout the unit is essential for teaching for conceptual change. A good assessment in teaching science helps to evaluate students acquisition of concepts, skills and attitudes. Literature reveals that variety of assessment strategies can be used in assessing students conceptual understanding of science concepts [6;11] because students in a classroom are individually different and some students best express in writing while others talking, demonstrating or drawing. Students' drawings is a powerful instrument of assessing students' understanding and they provide insight into students' thinking [6;5]. Drawing is a form of assessment which allows student to respond in a variety of ways and they provide an evidence of assessment that other assessment strategies conceal [14]. According to [8] drawing is a useful strategy not only to assess student understanding of concepts but also to assess observation skills and to assess students' ability to communicate pictorially.

Reviewing the literature it was apparent that large number of researches have been conducted to understand the conceptions of light among students and teachers. [1;11;9;12]. [12] have conducted a study to understand pre-service teachers' understanding of light, sight and related concepts at different educational levels, from primary to higher education. The results of the study has shown that significant number of the participants were found not to be able to explain light related phenomena in scientific language, despite their knowledge about them. As they further concluded some common misconceptions about light, light sources and sight process have been determined at all levels. A study conducted by [3] dealing with students conceptions in geometrical optics, have found that misconceptions related to propagation of light, vision, refraction and reflection was compatible with the misconceptions in other countries.

None of such studies have been carried out in Sri Lanka. However [13] in her doctoral degree thesis concludes that some primary teachers are not very much concerned about their drawing to facilitate the learner in understanding concepts. As she further explains one such example is reflection of light through a plain mirror.

The aim of the research was to use students’ diagrams to assess conceptual understanding on ‘light’ concept of grade eight students. The objectives of the research were:

- to study grade eight curricular materials to understand the subject content related to light.
- to find out whether teachers use students’ diagrams to identify understanding of science concepts related to light.
- to analyze diagrams provided by students to explore students’ understanding of concepts related to light.

2. Methodology

The study was conducted in Kandy district in Sri Lanka with the use of mixed method approach.

2.1 Selection of sample

Convenience sampling was used in this research and total number of 6 schools were selected from Kandy and Denuwara education zones. Total number of 212 grade eight students were selected to administer the written question paper based on ‘light’. The teacher sample of this study was consisted of 52 science teachers those who were teaching at grade eight in Kandy and Denuwara education zones.

2.2 Data collection

Data were collected with the use of a written test for students, documents and a teacher questionnaire. Grade eight science syllabus, teacher instructional manual and grade eight science textbook were studied to understand the subject matter related to light. Based on a detailed literature review, written test with eight questions was constructed as a data collection instrument. The purpose of the test was to assess grade eight students’ understanding of light related concepts after instruction. Each question required a drawing according to a given description followed by a written explanation. Some of the questions in the test has been used in earlier studies. ([10];9). Areas addressed in each question are given in Table 1.

Table 1 Areas addressed in each question

Question No.	Area
1	Path of light
2	Vision
3	Mirror reflection
4	Mirror reflection
5	Refraction
6	Refraction
7	Refraction
8	Mirror Reflection

Questionnaire was administered to 52 secondary science teachers at Kandy and Denuwara educational zone. Questionnaire consisted of 14 questions out of which first five addressed the experience, professional qualifications and the educational qualifications. Questions 6-12 were based on assessment techniques used by teachers when assessing science knowledge on light concept. Last two open-ended questions addressed the difficulties faced by teachers when using drawing for assessing students and the suggestions made by teachers in order to use drawing for assessing science knowledge.

2.3 Data analysis

Students’ drawings for each question and their explanation were qualitatively analysed in order to reveal their conceptual understanding. Furthermore number of incorrect diagrams and percentage of students provided correct diagrams for each question were calculated. Data obtained from teacher questionnaire were analyzed with the use of SPSS statistical package.

3. Results and discussion

The results of the study present under two headings; student’s drawings and assessing students’ understanding.

3.1 Students’ drawings

Analysis of students’ drawings in each question revealed that they provided a large number of incorrect diagrams as given in Figure 1.

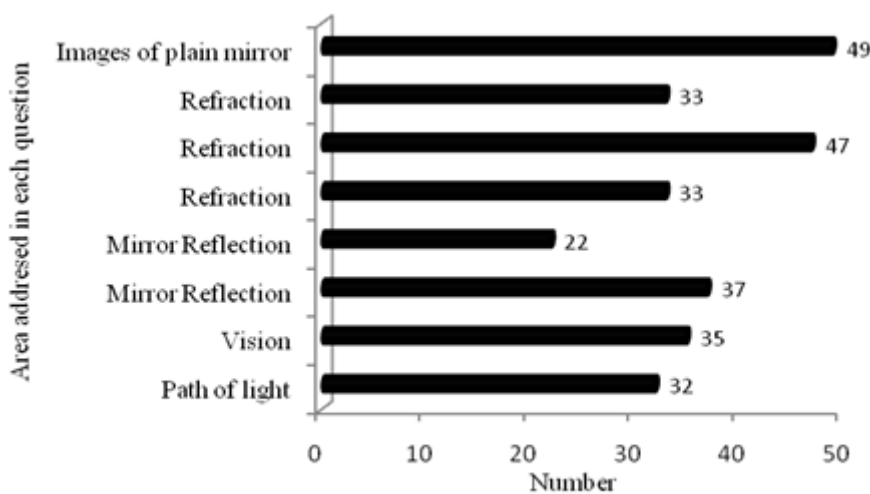


Figure 1 Number of incorrect diagrams provided by students

According to Figure 1 it was really surprising to observe that students drew more than twenty different diagrams for each question instead of the correct one. The highest number of incorrect diagrams recorded from question number 1 based on path of light and lowest was recorded from question 4 based on mirror reflection through a plain mirror. Providing incorrect diagrams for each question showed that students possessed a large number of misconceptions related to light related concepts; path of light, vision, mirror reflection, refraction, and images of plain mirror. One of the most common misconceptions among students was related with vision. Out of the total sample of students less than 37% of students were capable of providing correct diagram for each question as shown in Figure 2 below.

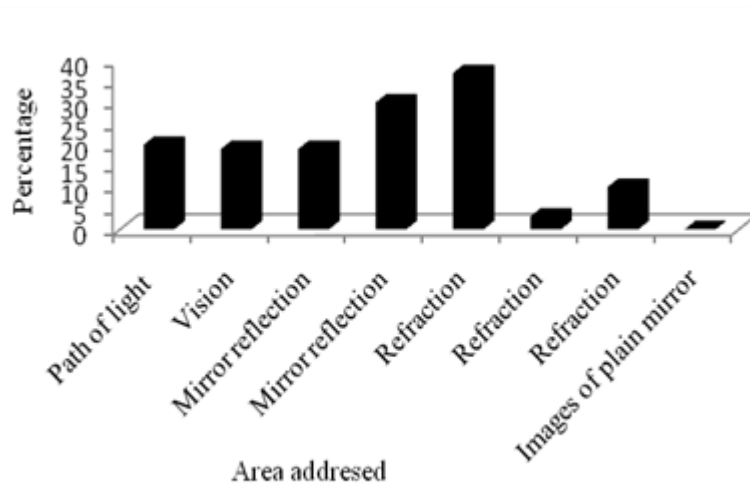


Figure 2 Percentage of students provided correct diagrams

The highest percentage of students were recorded from question number 5 which addressed the refraction through a plate of glass and lowest from question number 8 based on images of plain mirror. None of the student provided correct diagram for question number 8 which was based on images of plain mirrors kept in 90 degrees angle. It was further evident from students’ written explanations that less than 10% were able to provide correct explanation for their diagrams. The analysis of students drawing is further discussed under each question.

3.1.1 Path of light

In the first question of the written test students were expected to draw the path of light and provide explanation for their drawing as given below.

Question 01: Room A and B are adjacent rooms as given in diagram below (Figure 3). Suppose there is a small hole as shown in the centre of the very thin wall that separates the two rooms. Two very small bulbs are attached near the centre of the left wall of room. As shown in the figure both bulbs are lit and equally bright. Suppose you are sitting in the centre of room B and you would see two light spots on the right wall of Room B. Draw the path of two light rays in the diagram. Provide explanation for your drawing.

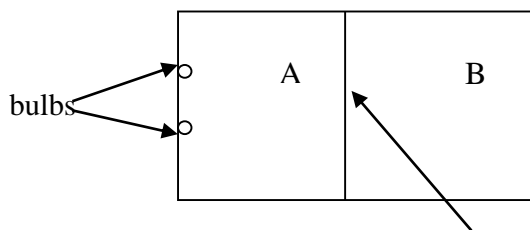
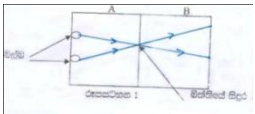
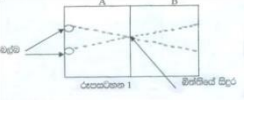
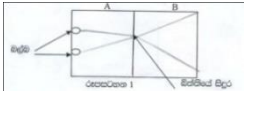
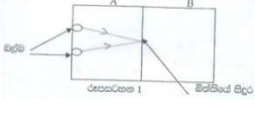
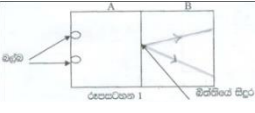
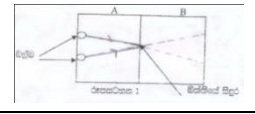


Figure 3 Diagram for question no.1

Out of thirty three different drawings, six with higher frequencies and percentages are presented in Table 2. As shown in Table 2, only 30% of the sample was able to provide correct drawing. It was further revealed from written explanation provided by the students, out of 20% who drew correct drawing only 45% were able to provide correct explanation: “Light travels in a straight line until it hits something”. Although 10% and 5% of students (diagram 2 and 6) drew straight lines those were not represented as light rays. Fourth and fifth were given as incomplete drawings. It was impossible to get clear reasons for those incomplete drawings.

Table 2 Examples of students' drawings in question 1

* correct diagram

Diagram	Frequency	Percentage %
	43	20
	20	10
	17	08
	16	08
	10	05
	10	05

3.1.2 Vision

The second question presented below was used to explore students' understandings of the vision concept.

Question 2; A light bulb is lighted in a room without any windows as you can see in the figure (Figure 4) below. Suppose you are standing in the middle of the room, draw a diagram of rays to show how you see the fan hanging on the roof. Provide reasons for your diagram.

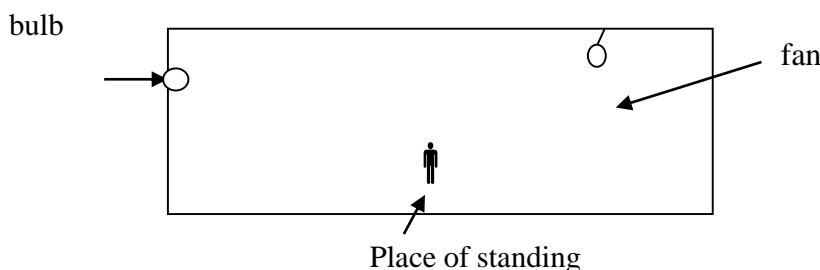
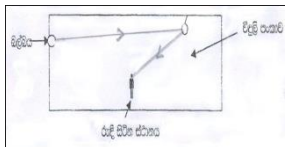
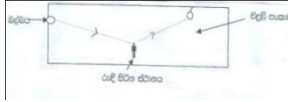
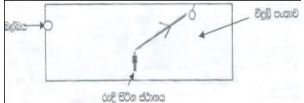
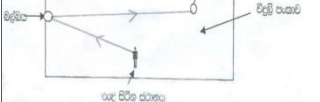
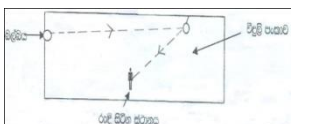
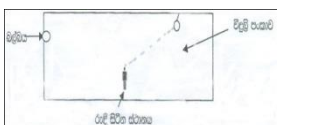


Figure 4 Diagram for question no. 2

It was surprising to see thirty seven types of students' diagrams. Out of all those different types, six were selected with higher percentages as given in Table below (Table 3). As it is given in the Table 3 less than 20% (19%) drew correct diagram. It was evident from the written explanation out of 19% who drew correct diagram, only 25% provided correct explanation: to be able to see the object, light coming from

the light source to the object which reflects it and then light goes into the eye. Instead of the correct explanation, a considerable percentage of students (14%) thought that light source to the eye and then to the object. Moreover diagrams and written explanation of some students (5%) showed that they understood it as light from eye to the source and to the object. Out of the total sample of students 9% of them were not provided any diagram. Some respondents drew diagrams (diagram 3) showing light went from eye to the object to be seen. All those drawings illustrated the students misunderstandings related to sight.

Table 3. Students drawing related to vision concept

Diagram	Frequency	Percentage %
* 	41	19
	30	14
	07	03
	11	05
	07	03
	09	04

3.1.3 Reflection

Item 3 and 4 of the written test assessed students understanding of reflection from a mirror

Question 3; A plan mirror is fixed to a room as given in the figure below (Figure 5). Draw rays to show how Amal who is standing in position A, sees the image of a nail on the right wall of the room. Provide explanation for your drawing

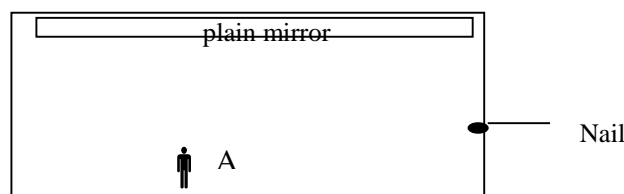
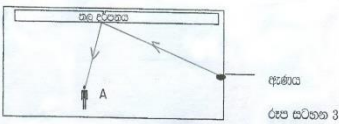
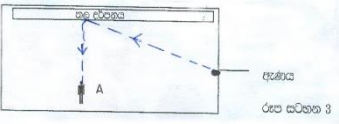
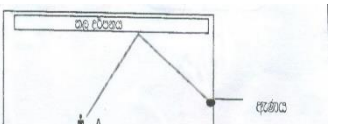
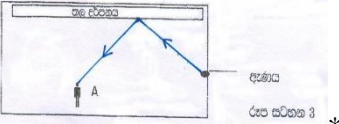
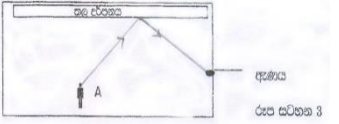
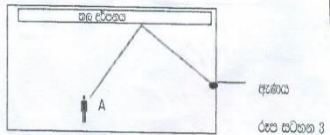


Figure 5 – Diagram for question no. 3

The results of the analysis are presented in Table 4. According to Table 4 only 19% of students were succeeded in providing correct drawing. This shows that majority of students do not have a correct conceptual understanding on reflection: The light rays from the nail hits the mirror and reflects through the mirror and comes to the eye. Moreover it was revealed from the first two diagrams that students are unaware of the law of reflection: angle of reflection similar to the angle of incidence. Although 20% of students provided diagrams (third and sixth) they were unable to mark the direction of light rays which is essential in drawing light rays. Table 4 Examples of students’ drawing for question No. 3

Table 4 Examples of students’ drawing for question No. 3

Drawing	Frequency	Percentage %
	23	10
	11	5
	10	5
	40	19
	16	8
	10	15

A considerable number of students (15%) were not provided any diagram to the question. Inability of drawing any diagram showed the lack of understanding related to the concept.

3.1.4 Reflection

Question no. 4 which assessed students’ understanding of reflection from a plain mirror is given below (Figure 6).

Question 4; A and B are two rooms of a house and doors of two rooms are opened. A mirror is fixed in Room A and a child is studying in room B in the marked place P. Suppose child can see the image of the vehicle through mirror. Draw a diagram of rays to show the path of light. Write an explanation for your drawing

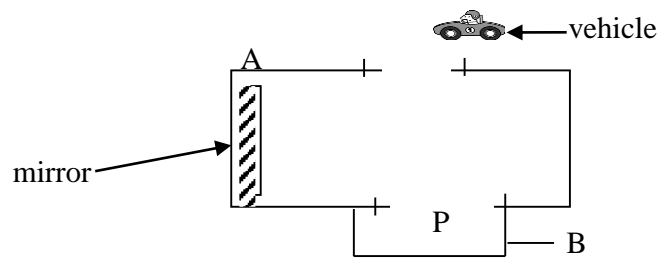


Figure 6 Diagram for question no. 4

Thirty eight students out of the total sample did not provide any diagrams and the rest provided 23 different diagrams. Six drawings with higher frequencies are shown in Table 5.

Table 5 Examples of students drawings in question No. 4

Diagram	Frequency	Percentage %
	65	30
	15	7
	13	6
	14	6
	10	4
	10	4

Data revealed that a considerable percentage (30%) of students’ drawings agree with the scientific view. Most of the students (94%) who drew correct diagram could not give acceptable reasons appropriately even though their drawing is correct. However their explanations included incomplete answers: “Light rays coming from the vehicle reflects and gets image”, “Light reflects through the mirror and we can see the vehicle”, “Light rays hits the mirror and image is seen”. As it is seen in the third diagram of the table some students drew arrows to show that light went from the eye to the mirror and then to the vehicle. In analyzing the latter three diagrams students have doubts regarding the direction of light rays. The direction of light rays

in the second and third diagrams provides and evident of misunderstanding of reflection through a plain mirror.

3.1.5 Refraction

In order to assess students’ ideas about refraction question no. 5, 6 and 7 were included in the written test paper. Question 05 given below tested the students’ understanding of refraction through a plate of glass.

Question 05; A light ray encounters the side of a plate of glass as shown in the diagram below. (Figure 7) Complete the path of the light ray and write reasons for your answer.

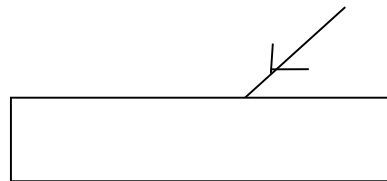
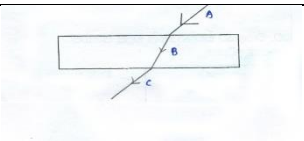
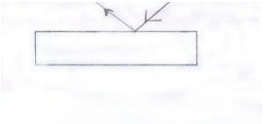
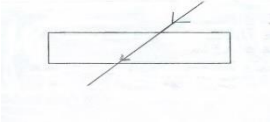



Figure 7 Diagram for question no. 5

‘Students responses represented 34 different drawings and Table 6 provides six diagrams with higher frequencies. Although 37% of students presented correct diagram, none of them provided appropriate explanation compatible with scientific explanation. However their explanations included partially correct answers:

- Light rays bends towards the normal when it moves from fast medium to a slow medium
- When light rays travels through a plate of glass the path of the rays is changed
- Because of reflection of light
- Light rays reflect
- When light travels from air to the glass and glass to the air its path is changed
- When light travels through one medium to another path of the rays changed
- Change the direction of light.

Table 6 Students’ drawings and percentages for question no. 5

Diagram	Frequency	Percentage %
	79	37
	26	12
	06	3
	06	3

	15	7
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It is evident from the above explanations students do not possess correct understanding about reflection of light. Although most of the students who provided second, third and fifth diagrams mentioned the reason as refraction they failed to provide correct drawing.

Question 6 also provided opportunities for students to demonstrate their understanding of the refraction'

Question 6; Student A wants to find out how depth of the basket fallen into a pond as it shows in the diagram below. Draw a diagram to show how students 'A' sees the marked point of the basket. Give reason for your drawing.

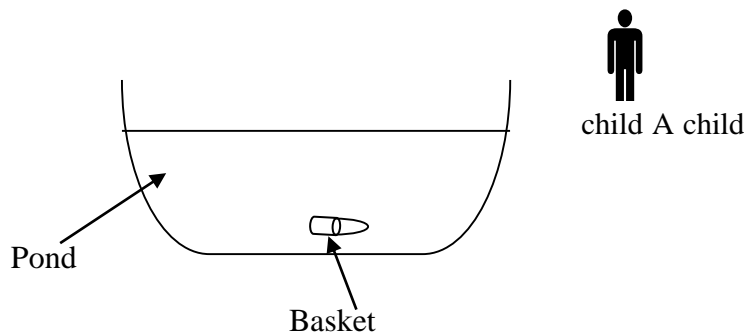
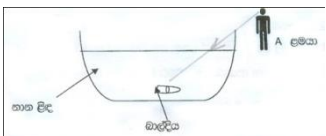
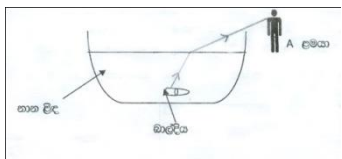
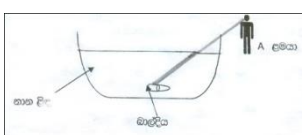
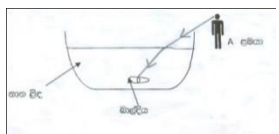


Figure 8 Diagram for question 6

It was able to identify 48 drawings different from each other but most of them (18) were recorded in very low percentages. Six drawings with higher frequencies are given in the Table 7.

Table 7 Students' drawings for question no.6

Diagram	Frequency	Percentage
	32	15
	06	3
*		
	13	6
	22	10

	12	6
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Nearly one fourth of the students (26%) did not draw any diagrams. The results given in the Table 6 is really surprising because only 06 students of the sample of 212 were able to draw a correct diagram. As it is seen from the above table most of the students drew a straight line without considering refraction incident at all. It is again evident from diagram four, lack of basic understanding of sight concept among students. As a result of this the direction of light ray has been drawn from eye to the object.

3.1.6 Refraction through a prism

Students understanding of refraction through a prism was assessed in question no. 7.

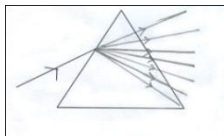
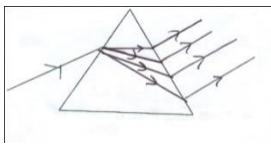
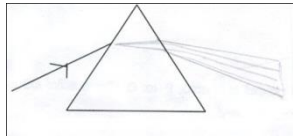
Question 7; A diagram below shows a white light ray hitting a prism. (Figure 9). Draw a diagram to show the path of the light ray. Write reasons for your drawing.



Students provided 34 types of drawings and three out of those drawings recorded in higher percentages are given in Table 8.

Figure 9 Diagram for question no. 7

Table 8 Examples of students drawings provided to question no. 07

Drawing	Frequency	Percentage
	24	11
	18	08
	21	10
*		

The data above provided evidence to show that only a 10% of students were able to produce the correct diagram. Out of those 10 %, 71% of students explanations were consistent with the scientific explanation. Another interesting point observed in analyzing data was most of the students who drew first diagram provided the reason: “Refraction the light when it hits the prism” Although they mentioned the terminology refraction, it is confusing whether they really understood the concept of refraction.

3.1.7 Mirror images

Question No . 9 given were presented to reveal students’ ideas about images of plain mirrors kept in an angle of 90⁰.

Question No. 9; The diagram below (Figure 10) shows two plain mirrors kept in 90 degrees.

Suppose a lighted oil lamp is kept in the place marked as x. Mark the places where you think as the images caused by two mirrors P and Q. State reasons for your answer.

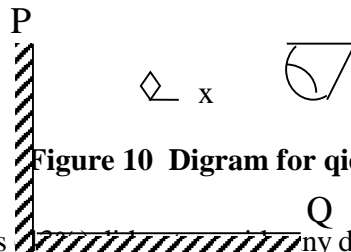


Figure 10 Diagram for question No 8

A large number of students provided any diagram for this question. Among the rest, forty nine types of diagrams were provided and only two examples indicating the places of the images are given with percentages. (Table 9).

Table 9 Examples of students drawings provided to question no. 08

Diagram	Frequency	Percentage %
	12	06
	12	07

None of the students’ diagrams do not completely compatible with the scientific view because when the two mirrors are kept in 90 degrees three images are formed. Furthermore distance to the object and mirror should be equal to the distance to the image and mirror. However five students out of twelve stated the formula of calculating the number of mirror images.

3.2 Assessing students understanding

Question number 3 of the teacher questionnaire addressed the methods used by teachers in assessing students. Responses revealed that practicals (42%), written tests (29%) and presentations (15%) were the most common methods used by teachers to evaluate conceptual understanding of secondary students’ science concepts.

Question no. 7 of the questionnaire focused on understanding whether teachers use drawing in written tests to assess students understanding of science concepts. 98% percent of teachers in the sample responded that they use drawing in the use of written tests for secondary students. Furthermore 96% percent of the sample responded that they used drawing for assessing science knowledge of grade eight students. Almost all teachers in the sample responded that drawing can be used in assessing students understanding on light concept.

Question number nine was constructed to understand the types of questions used by teachers in assessing grade eight students science knowledge. It was apparent from their responses that structured essay (71%) and

multiple-choice questions (17%) were the most common type of questions used in assessing science knowledge of grade eight students.

Last two open-ended questions were focused on difficulties encountered by teachers in using drawing in classrooms and suggestions to avoid those difficulties. Teachers were in the view that they face difficulties in using drawing in classrooms. Spending more time to draw diagrams correctly and drawing according to a scale were two most common problems encountered by teachers. Using advanced technological methods, giving an understanding of principles of drawing, drawing diagrams while explaining step by step were suggestions given by most of the teachers.

4. Conclusions and recommendations

The study reveals that drawings can be successfully used to assess students' understanding of concepts related light: path of light, vision, reflection and refraction. The study provides evidence that most of the students do not possess a correct conceptual understanding regarding concepts of light. Therefore they fail to provide the correct diagram and the explanation for the incidents given to them. The results of the study were supported by other studies in the literature [1;11; 9]. Although students provided the correct diagram according to the given description they had their doubts regarding the explanation. It is evident that students learn the content without understanding concepts in light.

In comparison the students' drawings with the results of the previous studies conducted in foreign countries, our students provided variety of different types of diagrams for each question. Moreover most of the students' written explanation are not consistent with the scientific view at all or partially correct answers. Providing number of diagrams for each question and explanations shows that students possess several misconceptions for each concept. Although higher percentage of teachers use drawings to assess light concept it is questionable whether students get feedback in order to correct their misinterpretations of their drawings.

The results of the study showed that drawings is an effective technique for assessing students understanding of science concepts. It is really a powerful tool to understand students' misconceptions in science concepts.

Drawings should be effectively used to identify misconceptions of students prior to the instruction. Teachers should be promoted to use drawings to assess students and provide feedback to avoid their misunderstandings. When using drawing in classrooms teachers should be very careful otherwise students get misconceptions.

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