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How Do Learners Conceptualize Plane Mirror Reflection? A Case Study of Grade 11 South African Learners

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KEYWORDS Alternative Conceptions. Errors. Optics. Light. Plane Mirror Reflection

ABSTRACT The focus of this paper is to understand how Grade 11 learners conceptualize image formation in a plane mirror. The sample consisted of 70 learners, selected by using the convenient sampling technique, from a selected urban senior secondary school in the Province of the Eastern Cape in South Africa. The mixed-method nature of the research design was accompanied by the use of the 4-Tier Optics Diagnostic Instrument (4ODI), which enabled the collection of both quantitative and qualitative data simultaneously. The findings emerged from the analysis of seven relevant questions of the 4ODI, which indicated that the learners had held four types of conceptions, that is, scientifically-accepted strong conceptions, scientifically-accepted weak conceptions, alternative conceptions, and errors due to lack of knowledge. It also emerged from this study that not all the correct responses of the participants could be justified by scientifically acceptable arguments.

INTRODUCTION

Learners enter the classroom holding prior knowledge about many scientific concepts. The information that a learner has acquired before entering the classroom will have an influence on his/her future learning (Demirbas and Ertugrul 2014). The prior knowledge might have been acquired by different means through daily life experiences, interaction with peers and elders, teachers, textbooks, audio-visual media and so on. Most researchers agree that the prior knowledge held by learners play a crucial role in the learning and teaching of any topic in science (Posner et al. 1982; Hewson and Hewson 1988; Langley et al. 1997; Yurumezoglu 2009; Taslidere and Eryilmaz 2015), and consequently, the way in which learners conceptualize different science topics has been a subject of research for many science education researchers all over the world. Optics may be considered as an area in which learners have rich direct experiences in their daily lives, from which they construct concepts regarding optics (Eshach 2010).

Several studies have been conducted about learners' conceptions of image formation in a plane mirror (Goldberg and McDermott 1986; Langley et al. 1997; Chen et al. 2002; Heywood 2005; Eshach 2010). These studies suggest that not all the identified conceptions held by learners are scientifically acceptable. Some of the alternative conceptions about plane mirror reflection reported in the study by Goldberg and McDermott (1986) were that 'the observer can see an image only if it lies along his or her line of sight to the object', 'an image would be in different positions for different observers and the lack of understanding of the role of eye in the perception of an image'.

Langley et al. (1997) used both diagrams and verbal explanations regarding many topics relating to optics such as shadows and diffused shadows, vision, pinhole images, mirror images and lens images. The study reported that only three learners in their sample could give correct verbal and diagrammatic descriptions of the mirror image formation and observation. Moreover, creating images was considered to be an inherent attribute of the silvery material, rather than the outcome of the reflection process. A similar finding was reported in a recent study conducted by Taslidere and Eryilmaz (2015). The study also reported several other alternative conceptions such as 'to see the image of an object, it should be inside the front region straight ahead of the mirror' and 'an observer can see the object because she/he directs sight lines toward it, with light possibly emitted from the eyes'.

Chen et al. (2002) concluded that a high percentage of senior high school students did not comprehend the nature and mechanism of image formation through mirror reflection. The results from the study conducted by Heywood (2005) among trainee teachers showed that the trainee teachers produced a variety of representations for how an image was seen in a plane mirror, and there was a lack of consistency in terms of how they represented their thinking.

In a study conducted by Watts (1985), the participants described the image as formed on the mirror surface rather than behind it. A similar finding was revealed in a recent study conducted by Eshach (2010) even though the learners knew that light rays hit the mirror and reflected from it and they somehow connected light rays with the image, this connection was vague. Many learners believed that the image could not be behind the mirror since the light rays (and consequently the image) could not get there. Thus, the nature of the alternative conceptions does not seem to vary according to time.

Even though attempts have been made by different researchers in several parts of the world to assess learners' prior knowledge regarding optical phenomena, not one such attempt could be located by the researchers in a South African context. Geometric optics is an important topic in the high school Physical Sciences' curriculum of South Africa, and Physical Sciences is one of the subjects in which learners perform very badly in the Grade 12 (matric) examination. In 2009, Physical Sciences, as a subject, had the lowest pass rate of all the subjects. In 2010, the pass percentage increased a little, but more than seventy percent of the 20,364 who wrote the Physical Sciences examination could not achieve more than forty percent and only 23.5 percent of the candidates were qualified for university studies (Du Plessis 2011). Moreover, the overall performance in the Eastern Cape was the worst. Yet, sufficient attempts are not being made to investigate the prior knowledge of learners in Physical Sciences generally, and optics in particular.

Objectives of the Study

According to the National Curriculum Statement (Grade R to 12) as stipulated by the Department of Education (DoE 2011), South Africa's Grade 11 learners are supposed to learn the optical phenomena reflection, refraction, total internal reflection, diffraction and interference under the core knowledge area of 'Waves, Sound and Light'. If meaningful improvement in both the achievement and the quality learning of Physical Sciences is to be fulfilled, it is important to make the necessary changes in the teaching and learning methods of the subject. Without understanding where the problems and deficiencies lie, it is meaningless to change the teaching or learning methods, or even the curriculum. This is why it becomes important to study the way learners conceptualize the subject and what their conceptions are. The purpose of this paper is therefore, to investigate Grade 11 learners' conceptual understanding of image formation in a plane mirror, in a selected senior secondary school in Mthatha District of the Eastern Cape Province of South Africa. Thus, the study sought to answer the following research questions:

- What type of conceptions about plane mirror reflection is held by the sample?
- To what extent did the participants present scientifically accepted justifications for their scientifically accepted answers (if any)?

METHODOLOGY

Sample

The sample for the study constituted Grade 11 learners from a selected senior secondary school situated in the urban region of Mthatha District of Eastern Cape province of South Africa. The school caters for Grades 10 to 12 and is well known for its academic excellence in terms of Grade 12 examinations (matric examinations). Physical Sciences and Mathematics are two compulsory subjects for all the students in the school. The school was conveniently chosen as the research site since one of the researchers was a Physical Sciences educator at the time when the research was conducted. Moreover, since part of the responses from each participant was to be analyzed qualitatively, the researchers decided not to include too many learners or too many schools in the study. The sample of the study, therefore, included a total of 70 learners from two Grade 11 classes that were taught by the same Physical Sciences educator and which belonged to the stream. The allocation of learners into various streams is done by the school in a random way when the learners are admitted in Grade 10, and the allocation is based on the optional subjects they choose. The Physical Sciences educator for the two classes was a highly experienced educator with a Masters degree plus a teaching qualification. The main selection criterion for the above two classes was that the researcher intended to include some kind of randomness in the selection of the participants (which was already done by the school itself) to compensate for the selection bias, which might

have caused because of the use of convenient sampling for the selection of the research site.

Research Design and Data Collection Instrument

This study formed part of a larger study, which aimed at enhancing learners' conceptual understanding of optics. The larger study adopted a quasi-experimental pre-test and post-test research design. However, this paper reports only on part of the pre-test findings of the larger study. The study adopted a mixed-method data collection strategy. The collection of both quantitative data and qualitative data was accomplished by developing a 4-tier Optics Diagnostic Instrument or simply, 4ODI. The developed 4ODI was a slightly modified version of the standardized two-tier test developed by Chen et al. (2002). The first tier in each question in the 4ODI was a multiple choice question, which included content-based alternatives for the particular question, the second tier asked about the participants' confidence levels for their answers to the first tier, the third tier was an open-ended question, which asked the participants to give a reason for their answer to the first tier, and the fourth tier was meant to assess their confidence level regarding their answer to the third tier. The content validity of the questionnaire was confirmed by two experts in the field, one holding a PhD in Education and the other one holding a PhD in Physics. Before the 4ODI assumed its final form, piloting of the questionnaire was done on Grade 11 learners from a senior secondary school, which was not part of the research site for the main study, and thereafter, necessary changes were made.

Evolution of the 4ODI

The instruments used by different researchers to document alternative conceptions vary from time to time. Many of the earlier studies used qualitative research instruments such as open-ended questionnaires and interviews. Although these methods do expose details about the conceptions/alternative conceptions held by learners in scientific areas, these methods have some disadvantages when the study is intended for a large sample. One such drawback regarding interviews, as reported by Chen et al. (2002), is that many investigators and a large amount of time are needed to interview a large number of students. Training a large number of investigators is another problem.

Even though the use of multiple choice questions is a viable alternative to interviews and other qualitative tools, especially when the focus is on determining the prevalence and distribution of alternative conceptions across a population, it cannot differentiate correct answers based on correct reasoning from those based on incorrect reasoning. Even though two-tier multiple choice questionnaires (1st tier as the answer tier, a content-based multiple choice question, and 2nd tier as the reason tier, which is also of multiple choice type, but provides possible reasons for the 1st tier as its alternatives) could overcome this drawback, it is unable to segregate mistakes due to lack of knowledge from mistakes due to genuine alternative conceptions (Chen et al. 2002; Caleon and Subramaniam 2010a,b). To fill the void left in the multiple choice questionnaires in the previous studies, Caleon and Subramaniam (2010a) developed and applied a three-tier test on the nature and propagation of waves by including a combined confidence rating (as the 3rd tier) for both the answer tier (1st tier) and the reason tier (3rd tier) together for each question. In the same year, Caleon and Subramaniam (2010b) modified the above three-tier test by including separate confidence ratings for the first two tiers of the "answer tier" and the "reason tier", and the test was called the Four-tier Wave Diagnostic Instrument (4WADI). In the 4WADI, the first tier was a content-based multiple choice question, the second tier was meant to rate the respondents' confidence levels (using a 6-point confidence scale) for their answers to the first tier, the third tier asked the respondents to choose a reason (from the given alternatives) for their answer to the first tier, and the fourth tier rated the respondents' confidence level for their answers to the third tier.

The notion of using confidence ratings associated with responses to multiple choice questions can also be traced back in the study conducted by Hasan et al. (1999), wherein the researchers used the Certainty of Response Index (CRI) in conjunction with answers to multiple choice questions. The researchers assert that a student who chose a correct answer and reported a high certainty of response should be classified as having adequate knowledge and understanding of the concept, but a high certainty

of response accompanied by an incorrect answer would indicate the presence of alternative conceptions. Similar ideas were also observed in studies done in mechanics (Reif and Allen 1992; Oliva 1999; Potgieter et al. 2010), chemistry (Potgieter et al. 2005), biology (Bowen and Roth 1999) and mathematics (Yazdani 2006).

The 4ODI designed for this study incorporated many ideas of Caleon and Subramaniam (2010b). These researchers designed the 4WADI to assess learners' knowledge of 'waves'. However, such an attempt could not be found for any topic in optics. The 4ODI developed in the present study are, however, slightly different from the 4WADI developed by Caleon and Subramaniam (2010b). Firstly, the 4WADI included a 6-point confidence scale for both the answer tier and the reason tier, whereas the 4ODI included a 4-point confidence rating for both the answer tier and the reason tier. Secondly, instead of giving pre-set options in the third tier as in the 4WADI, the participants were given the freedom to respond in their own way in the third tier of the 4ODI, by answering an open-ended question. The advantage of using such an open-ended question in the third tier is that the researchers did not delimit the conceptions of the learners by giving pre-set options and thus, by the use of open-ended questions in the 3rd tier of each question of the 4ODI, and analyzing qualitatively the learners' responses, the researchers could obtain an in-depth understanding of the learners' conceptions/alternative conceptions. The researchers could thus use the 4ODI as an instrument, which could collect both quantitative and qualitative data simultaneously and with equal importance, thus making it very effective and useful as a data collection instrument for mixed-method research designs.

Data Analysis Techniques

To address the first research question, the responses to the first tiers of the 4ODI were analyzed quantitatively using the statistical package SPSS, Version 22. The SPSS was used to calculate the mean confidence level for each of the learners' responses and then to categorize the various conceptions according to their mean confidence level. The identified conceptions (from the responses to the first tier) were categorized into four based on the mean confidence levels as determined from the responses to the corresponding 2nd tiers:

1. Scientifically accepted strong conceptions: Correct 1st tier responses, which are associated with a high value of mean confidence level
2. Scientifically accepted weak conceptions: Correct 1st tier responses, which are associated with a low value of mean confidence level
3. Errors due to lack of knowledge: Incorrect 1st tier responses, which are associated with a low value of mean confidence level
4. Alternative conceptions: Incorrect 1st tier responses, which are associated with a high value of mean confidence level.

The second tiers of the 4ODI were analyzed by following a similar method to that of the analysis of Likert-type questionnaires. To calculate the mean confidence level associated with a particular conception, the options A, B, C and D were allocated values from 4, 3, 2 and 1 respectively, and then calculated the weighted average of the responses of all the participants for that particular question using SPSS. An arbitrary value of 3 was chosen as the cut-off value to determine whether or not a conception was strong or weak, that is, if the mean confidence level associated with a particular conception was 3 or more, it was considered as a strong conception (either scientifically-accepted strong conception or alternative conception) and a conception with a mean confidence level below 3 was considered as a weak conception (either scientifically-accepted weak conception or errors due to lack of knowledge).

The second question was addressed firstly by the qualitative analysis of the 3rd tier responses. The qualitative analysis was done by arranging the responses for a particular question from all the participants together and then developing categories from the responses for each question. This was followed by the calculation of the mean confidence level associated with each of the identified categories.

RESULTS

Types of Conceptions held by the Participants about the Characteristics of the Image Formed in a Plane Mirror

The prevalence of different types of conceptions, that is, scientifically accepted strong conceptions (SASC), scientifically accepted weak conceptions (SAWC), alternative conceptions (AC) and errors due to lack of knowledge (ELK), for all 7 questions in the 4ODI is given in Table 1.

Table 1: Fractional occurrence of learners' responses to various questions

Question number	*Fractional occurrence of learners' responses (%)*			
	SASC	*SAWC*	*AC*	*ELK*
1	44.3	-	31.4	24.3
2	-	57.2	15.7	27.1
3	-	28.6	34.3	37.1
4	-	28.6	-	71.4
5	-	18.6	-	81.4
6	-	18.6	-	81.4
7	-	27.1	-	72.9

It was noted from Table 1 that the most prevalent type of conceptions the learners held about plane mirror reflection was 'errors due to lack of knowledge'. This type of conceptions was found to be more prevalent in questions starting from 4 to 7. The scientifically-accepted strong conception was found to be held by the participants only in the case of Question 1. For all the other questions, the participants who responded correctly were found to do so with low levels of confidence and so such conceptions were termed as 'scientifically-accepted weak conceptions'. Moreover, alternative conceptions were found to be held by the participants only for a few questions (Questions 1, 2 and 3). Some of the identified major conceptions are listed in Table 2.

The results in Table 2 indicate that since majority of the incorrect answers were not rooted in strong beliefs, the term 'alternative conceptions' seems inappropriate for such concep-

Table 2: Percentage occurrence of various types of learners' conceptions

Question number	*Category of conceptions*	*Percentage occurence of responses*
	Scientifically-Accepted Strong Conception	
1	For the image of an object to be clearly seen in a plane mirror, the source of light should be aimed at the object	44.3
	Scientifically-Accepted Weak Conceptions	
2	The locations of the image seen in a plane mirror by both the observers sitting in front of the plane mirror are the same	57.1
3	Only the boy can see the image	28.6
4	When the source of light is moved up, the location of the image of the pencil seen by the observer remains the same	28.6
5	When the object is moved a little away from the mirror, the height of the image seen by the observer remains unchanged	18.6
6	When the observer moves a little away from the mirror, the location of the image of the pencil seen by the observer remains unchanged	27.1
	Alternative Conceptions	
1	For an image to be seen clearly in the mirror, the flashlight should be aimed at the plane mirror	17.1
2	Th location of the image seen by the boy is on the left side of that seen by the girl	15.7
3	Only the girl can see the image	31.4
	Errors Due to Lack of Knowledge	
1	For an image to be seen in the mirror clearly, the source of light should be aligned parallel to the mirror	20
2	The location of the seen by the boy is on the right side of that seen by the girl	18.6
3	Only the girl can see the image	18.6
3	Both can see the image	18.6
4	When the source of light is moved up, the location of the image seen by the observer moves up	24.3
4	When the source of light is moved up, the location of the image seen by the observer moves down	37.1
5	When the source of light is raised a little higher, the image will become longer	31.4
5	When the source of light is raised a little higher, the image will become shorter	45.7
6	When the object is moved a little away from the mirror, the image seen by the observer becomes longer	31.4
6	When the object is moved a little away from the mirror, the image seen by the observer becomes shorter	50
7	If the observer moves a little further from the mirror, the image will retreat from the mirror	31.4
7	If the observer moves a little further from the mirror, the image will approach the mirror	25.7

tions, and instead these conceptions should be viewed as 'errors due to lack of knowledge'. Moreover, a scientifically-accepted strong conception was identified only for the first question and the correct responses for all the other questions should be considered as scientifically-accepted weak conceptions because of the low levels of confidence associated with such responses.

The Extent to which the Participants could Justify their Correct Responses to the 1st Tiers

As can be seen from Table 1, the highest occurence of scientifically-accepted weak conceptions was observed for Question 2. However, the qualitative analysis of the learners' responses to the 3rd tier of the question showed that even though most of the learners managed to pick the correct answer from the given options, they had not held the correct conceptual understanding in this regard. Following are some of the explanations used by the participants to justify their correct answers to the 1st tier of Question 2:

Since the object is placed in the middle of the observers, the location of the image will be the same for the two observers.

Since the distance between the first observer and the mirror is the same as that between the second observer and the mirror, the location of the image seen by the two observers will be the same.

The mean confidence levels calculated (from the 4th tiers) indicated that the strength of the above conceptions were higher enough for these to be considered as alternative conceptions. Such instances were found in other questions too, for example, the correct responses for Question 3 were found to be justified by the following incorrect arguments:

Image is visible only to that observer who sits far away from the object.

Image of the object placed left to the mirror is visible only to that observer who sits to the right of the mirror and vice versa.

To justify the correct responses in Question 7, the following incorrect argument was found to be used by many respondents:

Image position depends only on the position of the lamp, mirror and the object.

Only two instances were found where the correct responses were justified by the use of scientifically acceptable arguments, for example, the correct answer for Question 4 and Question 5 were found to be justified using the following scientifically acceptable arguments:

As long as the object is not moved, the image will stay in the same place no matter where the lamp is moved (Question 4).

Image size changes only when the object size changes (Question 5).

Even though most of the incorrect responses were not justified clearly, there were some questions for which the partcipants' responses to the 3rd tiers led to some common conceptions, for instance, most of respondents who thought that the flashlight should be aligned parallel to the mirror for the image to be viewed clearly (see Question 1 in the Appendix) justified their answer incorrectly in the following way:

Both the object and the mirror must be lit up simultaneously.

For the same question, the respondents, who considered the flashlight should be aimed at the plane mirror, were found to have held this conception based on the following reasoning:

In order for the light to be reflected by the flashlight, the light must be aimed at the mirror.

Similarly, the incorrect responses for Question 2 were found to have originated from the following incorrect conceptions:

The observer on the left side views the image on the right side and vice versa.

The image appears at the same side as that of the observer.

The qualitative analysis of the 3rd tiers thus revealed that not all the correct responses originated from a strong correct conceptual understanding.

DISCUSSION

The findings of the study unveil several incorrect conceptions that the participants held about image formation in a plane mirror. The incorrect ideas identified amongst the participants of this study using the 1st tier of the 4ODI were also identified in previous studies. Some of the major errors due to lack of knowledge reported in this study are, 'when the source of light is moved up, the location of the image moves up' (24.29%), 'when the source of light is moved up, the image goes down' (37.14%), 'when the source of light is raised a little higher, the image becomes longer' (31.43%) and 'when the source

of light is raised a little higher, the image becomes shorter' (45.71%). Similar findings were reported in the recent study conducted by Taslidere and Eryilmaz (2015) in that 'in the presence of an illuminant, the position and size of the image of an illuminated object depends on the position of the illuminant'. Moreover, the alternative conception reported in this study, which says 'for an image to be seen clearly in the mirror, the source of light should be aimed at the plane mirror' (17.14%) was reported in the study by Taslidere and Eryilmaz (2015) too, as 'to see him/her in a plane mirror in a dark room, s/he should illuminate the mirror than herself/himself'.

The findings imply that not all the correct responses of the participants originated from their strong conceptual understanding. Moreover, not all the incorrect responses were strong enough to be considered as alternative conceptions. The incorrect responses out of a weak conceptual understanding were considered as errors due to lack of knowledge. While 'errors due to lack of knowledge' were identified in all 7 questions used in the present study, 'alternative conceptions' were identified in only 3 questions. Similarly, the correct answer chosen by a participant might not indicate a strong conceptual understanding of the related scientific concept, as some correct answers might have been guessed.

It emerged from this study that most of the correct responses in the 1st tier were supported by incorrect arguments. This was well evident in the justifications given for the correct responses to Questions 2, 3 and 7. This again supports the finding from the previous studies that multiple choice questions lack the ability to differentiate the correct answers based on correct reasoning from those based on incorrect reasoning (Caleon and Subramaniam 2010b). Only a few instances (Questions 4 and 5) were found where the learners managed to support their scientifically-acceptable answers with scientifically-acceptable arguments.

A comparison of the responses compiled from the participants' responses to the 3rd tier of the 4ODI with the options given as the 2nd tiers (reason tiers) in the two-tier instrument developed by Chen et al. (2002) showed that the 4ODI revealed conceptions/alternative conceptions, which could not be revealed from the study conducted by Chen et al. (2002). To cite a few, 'since the distance between the first observer and the mirror is the same as that between the second observer and the mirror, the location of the image seen by the two observers will be the same', 'image is visible only to that observer who sits far away from the object' and 'image position depends only on the position of the lamp, mirror and the object'. The questionnaire designed by Chen et al. (2002) asked the participants to use a set of ray diagrams (for each question) as the options for the 2nd tier (reason tier) to justify their answers to the 1st tier (answer tier). On the other hand, the 4ODI asked the participants to write their own explanations in the 3rd tier (reason tier) to justify their answers to the 1st tier (answer tier). Consequently, this study adds significantly to the existing literature of learners' conceptual understanding of plane mirror reflection.

CONCLUSION

The study sought to assess how Grade 11 learners in a selected senior secondary school in South Africa conceptualized plane mirror reflection. The findings of the study provided rich information regarding the alternative conceptions and errors held by the learners about image formation in a plane mirror. However, since majority of the incorrect answers were not rooted in strong beliefs to call them 'alternative conceptions', these conceptions should rather be viewed as 'errors due to lack of knowledge'. Even though the participants could correctly respond in some situations, they were not satisfactorily successful in justifying their correct answers with scientifically-acceptable arguments. The study thus concludes that Grade 11 learners' conceptual understanding of plane mirror reflection is weak and that the majority of the incorrect responses identified were errors due to lack of knowledge and not alternative conceptions.

RECOMMENDATIONS

The findings of the study proved that many learners did not seem to have understood the roles of the observer and the source of light in the image formation by a plane mirror, and this led most of them to choose incorrect answers for their responses to the questions in the questionnaire. Therefore, educators must make sure that the discussions about ray diagrams in the image formation in plane mirrors include the observer and the light source. Moreover, educa-

tors should take great care in considering their learners' prior knowledge when planning instructional methods to teach any science topic in general, and in particular, optics. The studies, which used four-tier tests or even three-tier tests in identifying the conceptual understanding of scientific areas could not, however, be located in South Africa, especially in the field of science education. The researchers' attempt at designing and using the 4-tier Optics Diagnostic Instruments in assessing the learners' conceptual understanding was therefore found to be an effective and novel approach in the field of science education in South Africa. The 4ODI developed in the present study becomes an effective tool, which might be very useful for Physics education researchers, who are interested in mixed-method research studies.

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APPENDIX

Questionnaire used in the study

QUESTION 1

At midnight, James is awakened by mosquito bites on his chin. He takes a flashlight and faces a mirror. In his darkened bedroom, if he wants to see his chin in the mirror very clearly, at what should he aim the flashlight?

1.1. Please check
(A) The flashlight should be aimed at the plane mirror.
(B) The flashlight should be aimed at his chin.
(C) The flashlight should be aligned parallel to the mirror.
(D) The direction in which the flashlight is aimed doesn't make any difference.
(E) _____

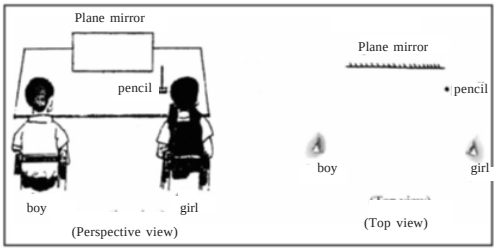
1.2. How sure are you of your answer?
A) Certain B) Almost certain C) Almost a guess D) A total guess

1.3. Write a reason for the choice of your answer for 1.1.

1.4. How sure are you of your reason?
A) Certain B) Almost certain C) Almost a guess D) A total guess

QUESTION 2

As shown in the left figure, a plane mirror and a pencil are placed on top of a table. A boy and a girl sit side by side in front of the table, looking into the mirror. The relative locations of the pencil, mirror, boy and girl are shown on the right.



2.1. Which of the following statements is correct? (Please check)
(A) The locations of the image seen by both students are the same.
(B) The location of the image seen by the boy is on the right side of that seen by the girl.
(C) The location of the image seen by the boy is on the left side of that seen by the girl.
(D) _____

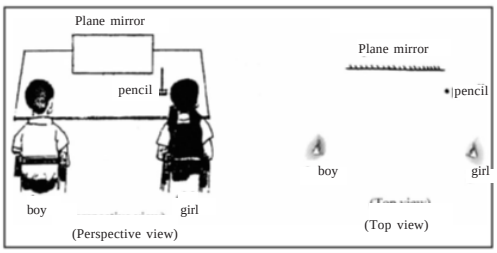
2.2. How sure are you of your answer?
A) Certain B) Almost certain C) Almost a guess D) A total guess

2.3. Write the reason for your answer for 2.1.

2.4. How sure are you of your reason?
A) Certain B) Almost certain C) Almost a guess D) A total guess

QUESTION 3

This follows the above problem: If the pencil is moved to the right until it reaches the edge of the mirror, and if both students move further apart until they are beyond the region perpendicular to the mirror as shown in the figure, are they still able to see the image of the pencil?



3.1. Please check:
(A) Only the boy can see the image.
(B) Only the girl can see the image.
(C) Both can see the image.
(D) Neither can see the image.
(E) _____

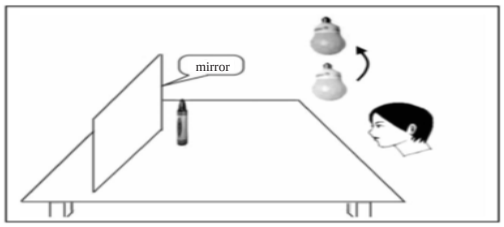
3.2. How sure are you of your answer?
A) Certain B) Almost certain
C) Almost a guess D) A total guess

3.3. Write the reason for your answer for 3.1.

3.4. How sure are you of your reason?
A) Certain B) Almost certain
C) Almost a guess D) A total guess

QUESTION 4

A plane mirror and a pencil are placed on a tabletop. An observer is looking into the mirror to observe the image of the pencil. The experiment is performed in a darkened room. A lamp is the only illuminant inside the room.



4.1. If the lamp is raised a little higher, what will happen to the location of the image of the pencil seen by the observer? Please check.
(A) It will move up.
(B) It will move down.
(C) It will stay in the same place.
(D) _____
4.2.How sure are you of your answer?
A) Certain B) Almost certain
C) Almost a guess D) A total guess
4.3. Write the reason for your answer for 4.1.

4.4. How sure are you of your reason?
A) Certain B) Almost certain
C) Almost a guess D) A total guess

QUESTION 5

This follows above question: If the lamp is raised a little higher, what will happen to the height of the image of the pencil seen by the observer?
5.1. Please check:
(A) The image will become longer.
(B) The image will become shorter.
(C) The image will remain unchanged.
(D) _____
5.2. How sure are you of your answer?
A) Certain B) Almost certain
C) Almost a guess D) A total guess
5.3. Write the reason for your answer for 5.1.

5.4. How sure are you of your reason?
A) ` Certain B) Almost certain
C) Almost a guess D) A total guess

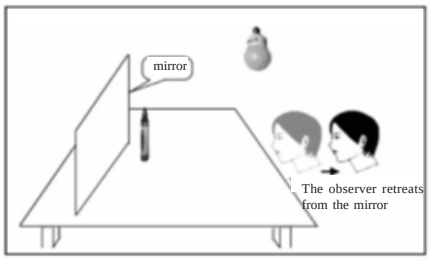
QUESTION 6

This follows the above question: The lamp stays fixed. The pencil is moved a little farther from the mirror. What will happen to the height of the image of the pencil seen by the observer?
6.1. Please check:
(A) The image will become longer.
(B) The image will become shorter.
(C) The image will remain unchanged.
(D) _____
6.2. How sure are you of your answer?
A) Certain B) Almost certain
C) Almost a guess D) A total guess
6.3. Write the reason for your answer for 6.1.

6.4. How sure are you of your reason?
A) Certain B) Almost certain
C) Almost a guess D) A total guess

QUESTION 7

This follows the above question: Instead of moving the pencil, if the observer moves a little further from the mirror while the lamp stays fixed, what will happen to the location of the image of the pencil seen by the observer?



7.1. Please check:
(A) It will retreat from the mirror.
(B) It will approach the mirror.
(C) It will stay at the same location.
(D) _____
7.2. How sure are you of your answer?
A) Certain B) Almost certain
C) Almost a guess D) A total guess
7.3. Write the reason for your answer for 7.1.

7.4. How sure are you of your reason?
A) Certain B) Almost certain
C) Almost a guess D) A total guess

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