

**An investigation of an innovative teaching approach to explore
how Grade 11 Physical Science learners make sense
of the topic light**

A thesis submitted in fulfilment of the requirements of the degree

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By

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Declaration

I declare that the work contained in this thesis is my original work. It has not been previously submitted in any form for assessment or degree in any other higher education institution. All ideas, quotations and other materials used in this study that were derived from the work of other people have been indicated in the list of references.

Signature:

A handwritten signature in black ink, appearing to be 'R. H. G.', written over a horizontal line.

Date: 06 April 2017

Dedication

I dedicate this work to the Almighty GOD, my mother, Helena Jacob 'Katiti' and my father Erickson Alweendo Mutikisha. Dad and Mom, it was because of your support as from my childhood up to now that I successfully managed to achieve this professional and academic stage. The moral values, discipline and positive attitudes you have been inculcated into me as part of my upbringing had really shaped my life.

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Abstract

In the Namibian education curriculum the topic light is offered in Grade 7 Natural Science and Health Education (NSHE) and in Grades 10, 11 and 12 Physical Science. The Namibian junior secondary certificate (JSC) Examiners' reports for 2011 to 2013 indicate that more than 50% of learners have been performing poorly on questions on the topic light particularly on the questions related to the *properties of light*. Similarly, the Namibian senior secondary certificate ordinary (NSSCO) level Examiners' reports for 2011 to 2013 indicate that many learners struggled to answer questions related to *reflection and refraction of light*. These results triggered my interest to investigate how Grade 11 Physical Science learners make sense of the topic light based on their conceptions, experiences, prior knowledge as well as looking into factors that enable or constrain them in making sense of the topic *light*.

This research was a case study of one secondary school in Namibian urban area. It was carried out with 22 Grade 11 Physical Science learners through a designed ASEI-PDSI (Activities, Students, Experiment, Improvisation-Plan, Do, See, Improve) teaching intervention to explore how they make sense of the topic light.

Underpinned by an interpretive paradigm, the study tried to explore how learners make sense of the topic *light* through ASEI-PDSI teaching approach. Within the interpretive paradigm, a mixed method case study approach was adopted. In the context of this study the quan→QUAL design was applied. The study was informed by constructivism consisting of both cognitive and social constructivism as a theoretical framework looking into learners' sense making, prior knowledge and social interaction as well as knowledge construction. Convenience and purposive sampling were used to select those 22 grade 11 Physical Science learners.

The data were generated using tests (pre-test and post-test), questionnaires, stimulated recall interviews, lesson observations and video-stimulated recall interviews. Triangulation of data was employed to ensure validity and trustworthiness of the research findings. Prior the commencement of the study, informed consents were obtained in writing from the Director of Ohangwena Directorate of Education, school principal, Grade 11 Physical Science teacher, learners as well as from the parents of the learners involved in the study.

The findings of the study revealed that there was a positive shift in learners' sense making as it was reflected by the learners' post-test scores in comparison to the pre-test scores. The post

test scores were higher than the pre-test scores. The study thus recommends for the adoption of an ASEI teaching approach to be used during science lessons in schools in Namibia for better academic improvement.

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LIST OF ABBREVIATIONS AND/OR ACRONYMS

ASE-PDSI	Activity Student Experiment Improvisation-Plan Do See Improve
BICS	Basic Interpersonal Communication Skills
CALP	Cognitive Academic Language Proficiency
ESL	English Second Language
GR	Group
JSC	Junior Secondary Certificate
L	Learner
LoLT	Language of Learning and Teaching
LTSMS	Learning and Teaching Support Materials
MoEC	Ministry of Education and Culture
NSHE	Natural Science and Health Education
NSSCO	Namibia Senior Secondary Certificate Ordinary
NSSCH	Namibia Senior Secondary Certificate High
PEEOE	Predict Explain Explore Observe Explain
QUAL	Qualitative
Quan	Quantitative
R	Researcher

SRI(s)	Stimulated Recall Interview(s)
TIMSS	Trends in International Mathematics and Science Study
ZPD	Zone of Proximal Development

CHAPTER ONE: SITUATING THE STUDY

1.1 Introduction

The purpose of this study was to explore how Grade 11 Physical Science learners make sense of the topic light through the **ASEI-PDSI** (**A**ctivities, **S**tudent, **E**xperiment, **I**mprovisation-**P**lan, **D**o, **S**ee, **I**mprove) teaching approach (Changeiywo Ng'eno, Barchock, 2013).

This chapter introduces the study by looking into the background to the study, followed by the focus of the study, the research goal and questions. The significance of the study, the data gathering techniques, and the definition of key concepts in the study are highlighted. The chapter ends with a brief summary of each chapter of the thesis.

1.2 Background to the study

This study was motivated by my professional experience in teaching Grades 8-12 sciences for about 12 years and of being a Grade 10 Physical Science national examination marker. As a regional advisory teacher, I have the responsibility of guiding the Natural Science/Physical Science teachers as well as analysing learners' examination results in the region. It was through this that I found out that Grade 10 and 12 learners consistently perform poorly in the topic 'light', which is the focus of this study. I also consulted a variety of literature on how learners struggle to make sense of the topic light.

The Namibia Senior Secondary Certificate High (NSSCH) level Physical Science Examiners' Report (2011) records that many learners incorrectly defined refraction of light. Similarly, the Namibia Senior Secondary Certificate Ordinary (NSSCO) level Physical Science Examiners' Report (2012) states that Question 31 of the Paper 2 component was poorly performed with only about 30% of learners getting the correct answer regarding the properties of light.

The Namibia Senior Secondary Certificate High (NSSCH) level Physical Science Examiners' Report (2012) also indicates that Question 7 (a) of Paper 1 was poorly answered as many learners reasoned that sound needs a medium without referring to the particles. Furthermore, the report states that learners know that light travels faster in steel than in air, however they only explained that steel has more particles than air, instead of more particles per unit volume, referring to density. In the same vein, the NSSCO Examiners' report (2012) revealed that Question 1 (b) was poorly performed as the majority of learners could not draw the ray diagram correctly to explain how the eye sees the object

in clean water with regard to the refraction of light. This reason, and some others discussed below provide the rationale for this research study to explore how learners make sense of the topic 'light'.

1.2.1 The international context

Learners' performance in Physical Science internationally is reported to be poor, particularly on the advanced performance level. Reporting on the Trends in International Mathematics and Science Study 2011 (TIMSS 2011), Reddy, Areds, Juan, Prinsloo, Rogers, Visser, Winnaar and Zuze (2011) reveal that all the selected participating countries failed to achieve 50% in science advanced performance level in a given science achievement test. The TIMSS 2011 report suggests that learners all over the world are still struggling to perform well in science at all school levels (ibid).

In a research study conducted in Tanzania, King'aru (2014) revealed that the percentage of learners who scored grade A-C has been very low in science subjects compared to non-science-subjects. It is further reported that the performance has been on the decline since 2008 onwards, particularly in science subjects. Similarly, Dzana (2012) in the research conducted in Malawi reported that poor performance in science subject has been on the decline due to some of the following factors: Lack of practical activities, learners' perception that science is difficult and too little time allocated to practical lessons. The assumption why learners in most countries learners perform poorly in science subjects is based on those findings.

In addition, Mji and Makgato's (2006) study with Grade 11 learners in South Africa indicate that learners are still struggling with science contents. Alev, Uzun, and Karla's (2013) study with 30 Grade 8 learners and 26 Grade 11 learners in Turkey showed that the majority of the learners could not explain light-related phenomenon in scientific language, despite their knowledge about them. Their study indicated that some common misconceptions about light, light sources and sight process are present at all levels of schooling.

The study conducted at Michigan State University by Eaton, Sheldon and Anderson (1986) highlight learners' misconceptions about light by referring to learners who answered that peoples' eyes see or focus on object, instead of peoples' eyes detect the light that enters their pupils. The study revealed learners' misconceptions that peoples' eyes see the shape of an object or light rays that enter their eyes and carry images though, scientifically, peoples' eyes only detect the shape of an object based on the direction from which the light reflected off comes to their eyes. Learners' sense-making of the topic light is influenced by these misconceptions. They also explored learners' misconceptions of reflection, refraction, diffraction and absorption of light, colours, formation of images, and other properties of light.

In addition, John (2014) found out that some Grade 11 learners in South Africa had incorrect conceptions of reflection, refraction and total internal reflection, although these learners are very confident about these incorrect conceptions that constrain sense-making of science.

Emerging from these studies conducted internationally, it is clear that learners at different school levels are struggling to make sense of the topic light due to the fact that they produced alternative conceptions or misconceptions instead of scientifically approved answers.

In the next sub-section, I looked into learners' performance in the topic light in the Namibian context.

1.2.2 The Namibian context

In the Namibian education curriculum the topic light is offered in Grade 7 Natural Science and Health Education (NSHE) and Grades 10-12 Physical Science. The Namibian Grade 10 Physical Science syllabus 2010 covers two themes on the topic light, which are *concepts of light and properties of light*. Under properties of light, the syllabus further covers the following topics: *Transmission and absorption of light, reflection of light by mirrors and refraction of light*.

The Namibian Junior Secondary Certificate (JSC) Examiners' reports for 2011 to 2013 indicated that more than 50% of learners performed poorly in questions on the topic light, particularly, in the questions relating to the *properties of light*. Furthermore, the JSC Examiner's report (2011) stated that learners could not correctly answer questions based on properties of light, such as the formation of a *lunar eclipse* and a solar eclipse.

The JSC Examiner's report for 2012 presented that learners performed poorly on questions related to properties of light that can lead to the formation of shadows and properties of images formed in plane mirror. The reports indicated that learners interchanged the properties of a mirror image with those from the image from a lens (Ministry of Education, 2012).

Namibia Senior Secondary Certificate Ordinary (NSSCO) level Examiners' reports for 2011 and 2012 expressed a concern that many learners could not answer questions related to properties of light such as *reflection, refraction and absorption of light*. The reports further pointed out that learners failed to make sense of the application of reflection and refraction of light in everyday life. The NSSCO Examiner's report for 2013 highlighted that many learners seemed not to have any clue about the application of reflection in a periscope as they could not figure out how and where to draw the mirrors, let alone how light passes through the periscope. Similarly, Ministry of Education (2013) reports that learners wrote that reflected ray angle, which made it sound like a ray and an angle at the

same time, instead of angle of reflection, so it means they could not make sense of the questions and this led to poor performance.

1.3 Statement of the problem

The Namibian Science curriculum for Basic Education recognises the importance of teaching and learning of the topic light (Ministry of Education, 2010). However, there are various challenges that may prevent the effective learning that could enable the learners to make sense of the topic light. One of the challenges is learners' prior knowledge. Learners bring to science classrooms a mixture of scientific and non-scientific knowledge from their communities, leading to misconceptions of the topic light that may prevent sense-making among learners. Stears, Malcolm and Kowlas (2003) express concern that school science is different from some of the learners' prior knowledge from homes and communities which lead to such misconceptions. Learners' misconceptions could be influenced by their cultural and social background and thus prevent the proper sense-making of the topic light in science classrooms.

Another challenge that is identified as constraining sense-making is the lack of practical activities, particularly on the topic light, in the science classroom (MoE, 2011, MoE, 2012 & MoE, 2013). In Namibia most schools claim not to have sufficient scientific apparatus and equipment for conducting practical activities, as a result, only theoretical lessons are offered (MoE, 2011, MoE, 2012 & MoE, 2013). This challenge may constrain sense-making in the science classrooms. Apart from practical activities and prior knowledge, language as a tool for communication might have an influence on sense-making in learning science.

According to Maselwa and Ngcoza (2003), practical work in science motivates learners to predict, observe and explain as it enables learners to direct and adapt the activities emerging from their own experience. Additionally, the JSC and NSSCO Examiners' reports from 2011 to 2013 revealed that learners have been consistently performing poorly in answering questions on the topic light. Other researchers present that students have a lot of misconceptions about the topic light (Aydin et al., 2005; Eaton et al., 1986, Uzu et al., 2013). It is against this backdrop of the topic light that I decided to conduct a study to explore how Grade 11 Physical Science learners make sense of the topic light.

1.4 Significance of my study

- The findings of the study may be useful in informing Physical Science teachers in Namibia on how learners make sense of the topic light and some best practices that can be shared on effective teaching of the topic light;
- The study may inform Physical Science curriculum developers on appropriate learning objectives and competencies that can enable learners to make sense of the topic light. Consequently it can be used in developing necessary learning materials;
- The study may further inform the Physical Science textbook publishers and editors to adjust the learning content in such a way that it make sense to learners;
- The findings of this study could be a guiding tool to the JSC and NSSCO examiners on the appropriate and relevant questions with regard to the topic light; and
- The study may also be useful to the upcoming researchers, particularly to those who are interested in pedagogical science to use it as reference in expanding their educational research knowledge.

1.5 Research Goal

The goal of this study was to investigate how Grade 11 Physical Science learners make sense of the topic light.

1.6. Research questions

How do Grade 11 Physical Science learners make sense of the topic light?

To answer the main research question, the following sub-questions were explored;

1. What are the Grade 11 Physical Science learners' conceptions and experiences of the topic light before and after an ASEI-PDSI teaching intervention was implemented?
2. How does an ASEI-PDSI teaching intervention influence Grade 11 Physical Science learners' conceptual understandings of the topic light?
3. What factors enable or constrain Grade 11 Physical Science learners to make sense of the topic light?

1.7 Theoretical framework

The study is informed by the constructivist perspective as it concerns the way humans individually and collectively interpret the world. As part of the constructivism theory, the study focused on both cognitive and social constructivism to get the insights into exploring how learners make sense of the topic light. This is detailed in Section 2.8.

1.8 Data gathering techniques

The tools used in gathering data for this study were:

- Questionnaires;
- Pre-test and post-test;
- stimulated-recall interview; and
- Lesson observations.

1.9 Definition of Key concepts

It might be better to write these in alphabetical order.

ASEI-PDSI (Activities, Student-centred teaching, Experiment, Improvisation-Plan, Do, See, Improve) is an adopted type of learner-centred teaching approach in which learners are actively engaged in the learning activities. It makes teaching of science more practical, therefore more interesting, accessible and relevant to learners.

Cognitive constructivism is a Piagetian learning theory focusing on mental cognitions and how individual learners develop or construct a mental model of their worlds.

Constructivism is a learning theory in which meaning is believed to be constructed individually or collectively and not regard learners as passive. The theory advocates that knowledge is constructed but not pose to people.

Misconceptions are the alternative concepts/wrong ideas that are unscientific as a result of learners have been influenced by their prior knowledge or cultural beliefs.

Sense-making is when learners are able to understand new concepts emerging in the topic that is taught. It looks into whether learners are able to relate what is taught to what they know or experience and be able to make meaning of those concepts.

Social constructivism is a learning theory in which learning is believed to occur as a result of social interaction with knowledgeable individuals within the community. It emphasize that learning is an active social process in which individuals make meanings through the social interactions with other and with the environment they live in.

Practical activities are the range of learning activities that requires careful planning and clear identification of the purpose of the activities. Those activities can be field work, learners' presentations and working in laboratories. They allow learners to put into practice the theory and skills they are studying as well as to prove their hypothesis.

Prior knowledge is the knowledge acquired from community, home, previous grades or the environment, which may be scientific or non-scientific knowledge.

1.10 Thesis outline

The thesis consists of seven chapters and its structure is as follows:

Chapter One: Situating the study

This chapter presents a summary of the background and context of the study. Firstly, the international and Namibian backgrounds in relation to the research topic are highlighted. The chapter also states the significance of the study, outlines the research goal and questions. The theoretical framework and data gathering techniques are summarily described and followed by the definitions of key concepts used in the thesis. The chapter ends with some concluding remarks.

Chapter Two: Literature Review

In this chapter, I presented the literature relevant to my study. For example, learners' misconceptions of the topic light, sense-making, learners' prior everyday knowledge, practical activities in science teaching and an ASEI-PDSI teaching approach. Lastly, the chapter discussed the theoretical framework underpinning this study and ends with some concluding remarks.

Chapter Three: Research methodology

In this chapter, I presented the methodology I used in my research. I first presented the mixed method research consisting of both qualitative and quantitative study, which is informed by an interpretive paradigm. I further discussed different data generation techniques that I used as well as the inductive/deductive method applied to analyze the data. I discussed the following components of my research: the research site, participants, the ethical issues/consideration, validity and limitations of the study were also considered.

Chapter Four: Data presentation, Analysis and Discussion (Phase 1)

This is the data presentation, analysis and discussion chapter. In this chapter the learners' scores from pre-test and post-test are quantitatively presented, analyzed and discussed. The data gathered through questionnaires, learners' explanatory answers from pre-test and post-test and stimulated recall interviews with three selected learners based on the pre-test answers are qualitatively presented, analyzed and discussed with some few comments from me, the researcher.

Chapter Five: Data presentation, Analysis and Discussion (Phase 2)

In this chapter I qualitatively presented, analyzed and discussed data gathered through lesson observations and video recorded focus group stimulated-recall interviews (SRI). With regard to

inductive reasoning, the data interpretations were done by means of analytical statements which I developed from themes that emerged from the data.

Chapter Six: Summary of findings, recommendations and conclusions

Chapter six contains a summary of findings, recommendations, reflections and a conclusion. It highlights a few critical remarks about the study. I further make some suggestions for future research areas. It states the limitations of the study and I conclude by briefly discussing my personal reflections with regard to my academic growth.

1.11 Concluding remarks

In this chapter I outlined the context and background of the study. The chapter further presented the research goal, and questions, theoretical framework, significance of the study, data gathering techniques, the definition of key concepts used in the study and the thesis outline.

The next chapter presents relevant literature to the study.

2.1 Introduction

It is strongly outlined that the Natural Science learning area contributes to the foundation of a knowledge-based society by allowing teachers to empower learners with scientific knowledge, skills and attitudes to formulate hypothesis, to investigate, observe, make deduction and understand the physical world in a rational scientific way (Ministry of Education,2010). Thus, a knowledge-based society can only be realised when learners are able to make sense of scientific concepts in science classrooms (MoE, 2010).

As the present study explored how Grade 11 Physical Science learners make sense of the topic light through ASEI lesson interventions, it is expedient to have review of literature that informs this study in the following areas:

- Learners' sense-making in science learning;
- Namibia Science Curriculum;
- Learners' misconceptions of the topic light;
- Possible causes of learners' misconceptions on the topic light;
- Practical activities in science learning;
- ASEI-PDSI as a teaching approach which integrates practical activities.

The theoretical framework that informs the study is also discussed.

I now discuss each of these in detail below.

2.2 Learners' sense-making in science learning

Sutchcliffe and Weick (2005) state that sense-making is about the interplay of action and interpretation rather than the influence of the evaluation on choice. Learners' action and interpretation of learning content determine how they make sense of the science concepts. Similarly, sense-making is defined as "how people make sense out of their experience in the world" (Hoffman, Moon & Klein, 2006, p.70). It was further discovered that sense-making constitutes the expression of concepts that have been common currency in psychology (Hoffman et al., 2006). It is revealed that sense-making might essentially mean creativity, curiosity, comprehension, mental modelling, and situation awareness (Hoffman et al., 2006). Those concepts might serve as indicators and factors that enable learners to make sense of the science learning contents. Apart from these concepts related to sense-

making, Hoffman et al. (2006, p.71) further define sense-making as “a motivated, continuous effort to understand connections in order to anticipate their trajectories and act effectively”.

Forbes (2008) outlines strategies that can be applied to influence learners’ sense-making of science. He indicates that learners make sense of science concepts through raising questions, making predictions, fair testing, measurement, developing tables, the construction and use graphs and charts, explaining results and evaluating investigations. Forbes (2008) further believes that practical activities enable learners to make sense of science concepts through empirical evidence.

Ash (2004) believes that meaning is created dialogically over time, among collaborating speakers and listeners, and that science understanding is talked into being. It is through both scientific and non-scientific dialogue that sense-making can be realized. In the same vein, (Sutchcliffe & Weick, 2005) that sense-making organizes flux, labelling, retrospective, presumption, social, and systemic, action and organising through communication. Thus, sense-making can be influenced by social and cognitive abilities of individuals to give meaning to the various scientific phenomena.

It is expressed by Ash (2004) from the Vygotsky perspective that everyday ideas become more scientific over time, when learners are given assistance, in both formal and informal settings. It means the way learners make sense of school science can be influenced by their prior knowledge, home languages, and cultural background and social interactions.

It is outlined by Ballenger, Hundicourt-Barnes, Rosebery, Ogonowski and Warren (2001) that social, cognitive and linguistic practices are some of the most common potential barriers that constrain learners’ sense-making of the scientific concepts. Thus, it is discovered that learners bring with them ways of looking at the world representative of the environment in which they have been reared. These habits of mind or ways of knowing may not be compatible with scientific habits of mind or ways of knowing typically associated with scientific discourse (Ballenger et al., 2001). Furthermore, Ballenger et al. (2001) identify some barriers to learners’ sense-making of science such as: misconceptions, differences between home language and school science language, perceptions and negative attitudes toward science, prior knowledge, everyday ideas and day-to-day interaction with the physical world.

In the next section, I now discuss the Namibian science curriculum in relation to the learning of the topic light.

2.3 Namibian Science Curriculum

After independence, Namibia transformed a teacher-centred curriculum to learner-centred curriculum to ensure that teachers adopt their teaching methods to allow learners to be actively engaged in the learning activities (MoEC, 1993). It was highlighted that learner-centred education motivates learners' active participation and involvement during teaching and learning (ibid).

The NSSCO Physical Science (2010) (Grade 11-12) is divided into Physics and Chemistry section. The table below shows the topics covered in each section and the percentage of examination questions extracted from each topic:

Table 1: NSSCO Physical science curriculum (2010) examination weight (%) per topic

Section	Topic	Examination weight (%)
Physics	1. General Physics	17%
	2. Thermal Physics	5%
	3. Properties of waves include light and sound	12%
	4. Electricity and magnetism	20%
	5. Nuclear physics	5%
Chemistry	1. Experimental Techniques	2%
	2. Atoms, Elements, molecules and compounds	7%
	3. Stoichiometry	3%
	4. Chemical reactions	5%
	5. Acids, base and salts	4%
	6. The periodic table	3%
	7. Metals	5%

	8. Industrial uses and application Chemistry	5%
	9. Organic Chemistry	5%
	10. Environmental Chemistry	3%
	Total (%)	100%

The topic light represents 12% of the NSSCO examination question paper each year as illustrated in the table above. This makes it one of the crucial topics in the Namibian science curriculum, therefore it was essential for me to explore how learners make sense of this topic.

Furthermore, in the Namibian school science curriculum, the topic light is offered in Grades 7, 10 and Grades 11 to 12. The Grade 7 syllabus for 2015 covers the following topics under the theme light: basic concepts of light, dispersion of light, transmission, absorption, reflection and reflection by mirrors. The Grade 10 Physical Science syllabus for 2010 covers two themes on the topic light which are: concepts of light and properties of light. Under properties of light, the syllabus further covers the following topics: transmission and absorption of light, reflection of light by mirrors and refraction of light. While the Grades 11-12 Physical Science syllabus (2010) covers reflection of light, refraction of light, thin converging lens and electromagnetic spectrum.

The general learning objectives of the topic light in the NSSCO physical science syllabus (2010, p.14) indicate that learners are expected to understand different properties of light and their applications, while for the specific learning objectives on topic light, learners should be able to:

- Describe the formation, and give the characteristics, of an optical image formed by a plane mirror;
- Use the law angle of incidence=angle of reflection;
- Perform simple constructions, measurements and calculation;
- Define refraction as light entering or leaving a medium with different optical density;
- Describe the refraction, including angle of refraction, in terms of the passage of light through a parallel sided glass block;

- Determine and calculate refractive index using $n = \frac{\sin i}{\sin r}$;
- Describe and graphically represent the path of light through a rectangular glass block and triangular prism;
- Explain dispersion of white light into continuous spectrum;
- Explain colour;
- Outline the formation, and give the characteristics of an optical image formed by a converging lens (diverging lens only in reference to correction of sight);
- Describe the action of a thin converging lens on a beam of light (diverging lens only in reference to the correction of sight);
- Use the term focal length and focal point;
- Use and describe the use of a single lens on a beam as a magnifying glass; and
- Describe the eye as converging lens and describe the uses of lenses to correct short and long sight.

According to the junior secondary certificate (JSC) Examiner's report for 2011, learners lacked the understanding to answer the following questions;

- (i) State the property of light that cause a lunar eclipse; and
- (ii) Explain why, during eclipse, the moon appears black?

The report revealed that learners lacked the understanding of how and why a lunar eclipse happens. Furthermore, the report indicated that learners knew what lunar eclipse is but could not provide the accurate explanation of it (Ministry of Education, 2011).

The JSC Examiner's report for 2012 indicates that learners performed poorly in the following topics:

- Properties of light that causes the formation of shadow; and
- Properties of an image formed in plane mirror.

It emerged from JSC Examiner's reports for 2011 to 2012 that learners are finding it difficult to cope with questions related to the topic light. In the next sub-section I therefore discuss some learners' misconceptions about light that might lead to poor performance.

2.4 Learners' misconceptions of the topic light

In the context of school science, misconceptions/alternative conceptions may be defined as ideas which are wrong because they have been based on failure to make sense and understand the situation due to lack empirical evidences (John, 2014). Furthermore, Eaton et al. (1986) discovered learners' common misconceptions about light as opposed to the scientific conceptions as presented in the Table 2 below.

Table 2: Learners' common misconceptions about light

Issue	Misconceptions	Scientific conceptions
Nature of light	The nature of light may vary depending on the type of light or environmental conditions (beams, rays, room light, coloured light etc.)	Light is electromagnetic radiation of specific wavelength
Function of peoples' eyes	Peoples' eyes see or focus on objects	Peoples' eyes detect the light that enters their pupils
How people see the shape of objects	Peoples' eyes see the shape of an object or light rays that enter peoples' eyes carry images	Peoples' eyes detect the shape of the direction from which the light reflected off it comes to the their eyes

Source: Eaton et al. (1986)

Additionally, they found other misconceptions among students about light in areas of: reflection, refraction, diffraction and absorption of light, colours, formation of images, and other properties of light (Eaton et al., 1986). They state that learners believe that light only illuminates the surface, object or area to allow the eye to see. And light comes to our eyes and we can see the objects from that light and agree that light makes things brighter so that the eyes can focus (ibid).

Shapiro (1989) identifies most common misconceptions and learners' ideas about light and vision such as, learners believe that light only reflects from mirrors and shiny objects, reflected light is shine or glare not something associated with seeing object and some believe that light travel further at night. These are misconceptions that may be influenced by learners' prior knowledge.

Similarly, in their research across a number of grades levels (30 eighth grade primary school students, 26 eleventh grade secondary students, and 42 student teachers) in Turkey, Alev and Karal (2013) found that the majority of students were not able to explain light-related phenomenon in scientific language. They found some common misconceptions about light, light sources and sight process at all these grade levels.

In her study conducted in South Africa, John (2014) noticed that some learners had alternative conceptions that the image size in the plane mirror decreases when the viewer or observer moves away from the mirror and increases when the viewer move closer to the plane mirror. They could not notice that scientifically the image size and its location remains unchanged as it is not affected by the position and the distance change of the viewer (ibid). Furthermore, John (2014) highlighted that some students believe that the positions /location of image in the mirror change with the position change of the source of light by indicating that when the source of light is moved upward the reflection from light moves downward. So, their answer was not scientifically correct as the position of image remain unchanged despite the source of light change the position. It is further identified that most students have the misconception that when the light rays cannot penetrate the object, the image is formed due to refraction, hence they associated the refraction and reflection with the penetrating ability of an object and in this regard their answers were not scientifically accepted (ibid).

It is reported that most learners could not identify the ray of light from the touch to the object and be reflected by the mirror to the eyes so that the image can be seen (John, 2014).

From the literature discussed above, it is evidenced that learners have some misconceptions about the topic light. Some studies have provided the underlining causes of these misconceptions and these are discussed below

2.5 Possible causes of learners' misconceptions on the topic light

I now discuss some of the possible causes of learners' misconceptions and how they influence sense-making of the topic light.

2.5.1 How learners' prior everyday knowledge influences sense making

Prior knowledge refers to all the experiences, skills and knowledge about the subject matter learners bring to school (Roschelle, 1995). Furthermore, Roschelle (1995, p.37) explains prior knowledge as “a representation of fundamental ideas that enable learners to visualise regularities in the environment”. Stears, Malcolm and Kowlas (2003) express that learners' everyday knowledge and

purposes can be used in the curriculum in a number of ways. For example, as a starting point for learning science, as a reference point for thinking about the nature of science, and as a context for applying scientific ideas and skills.

Following the same line of thought, Srikantaih (2005) refers to prior knowledge as experiential knowledge that learners bring to school and this influences how they make sense of the learning contents.

Learners bring to school experiences from home, community and environment and this knowledge and experience is a potential that should be utilized and drawn into teaching and learning (Namibia. Ministry of Education, 2010). It could be argued that this is one of the reasons why it is imperative for science teachers to consider the prior knowledge that learners bring to the science classrooms as this may impede the construction of knowledge and scientific explanation of concepts in the formal science classroom environment.

Rochelle (1995) asserts that science teachers need to understand how learners' prior knowledge affects learning. In support, Stears et al. (2006) inform us that in order to succeed in teaching science, it is important to incorporate prior everyday knowledge as it contains concept development that is more successful and produces a greater achievement of crucial outcomes. Furthermore, to build on learners' experiences is vital to connect the science known by learners to their prior everyday knowledge in the teaching science (Stears et al., 2006).

Ryder (2001) accentuated that prior knowledge fosters a theoretical shift to viewing learning as conceptual change. In support, Mukwambo (2012, p.20) states that learners construct meaning of concepts taught if prior knowledge is taken into account. He further explains that consideration of prior everyday knowledge and experiences would engage learners into a new learning situation (ibid). He concludes that engaging learners' prior everyday knowledge could make the following possible:

- Students will know the focus/direction of the lesson;
- It makes it easy for students to start a discussion or team project; and
- It helps students get actively involved as they end up constructing science concepts.

According to Meyer (2004), teachers should appreciate what learners already know and develop learning experiences that provide them with opportunities to keep their knowledge to accommodate

new skills and scientific knowledge for better understanding of the topic. In the same vein, Cook (2006) states that learners make meaning of the classroom science based on what they already know. He indicates that prior knowledge has greater influences on learners' perceptions and attention.

Similarly, Kasanda, Lubben, Goaseb, Kandjeo, Marenga and Campbell (2005) in their research study carried out in Namibia, discovered that when taking into consideration the learning effect of the use of daily context in science teaching, the distinctions in the methods of skills and knowledge building in everyday and scientific domains needs to be recognised.

Meyer (2004) informs that teachers should be able to ask learners to use previous instruction to explain real life situation before going on to new materials. Concurring with Meyer (2004), Kasanda, et al. (2005) emphasize the need to use learners' existing knowledge/skills and include learners' everyday experiences in order to introduce a topic or as illustration after presenting theoretical context. Keogh Naylor and (1999), affirm that good science teachers are those who teach for deep understanding by using students' prior knowledge about science to guide lessons, providing experiences to test and challenge those ideas to help students arrive at complex understanding. To Stears et al. (2003), learners should be involved in the lesson presentations through the use of background and scientific knowledge in order for them to gain the necessary skills and knowledge.

Despite that learners' prior knowledge is important in the teaching and learning of science, there may be some misconceptions that may be influenced by learners' social background that the teachers should address. As Roschelle (1995) suggest, prior knowledge can produce mistakes but it can also give insights, which means sometimes the same element of prior knowledge can provide both an incorrect alternative to one theory and be a good illustration of a theory in another topic. Similarly, Oloruntegbe and Ikpe (2011) point out that many learners find it difficult to create a clear linkage between classroom science concepts and science concepts embedded in their everyday experiences. Hence, they propose that the teaching science should be based on what learners already know because most learners come to school with some prior knowledge obtained from their local environment that should be acknowledged in the classroom.

Furthermore, Kasanda et al. (2005) state that concepts in the scientific domain are based on rules and follow a coherent logic, while everyday concepts are based on experimental schema and are organised through associations with only limited coherence, this means that scientific domain requires strict rule-based reasoning. Likewise, Ryder (2001) asserts that the science in everyday context is regarded

by many scientists to be uncertain and unempirical. Lending support, Stears et al. (2003) explain that the science in the community differs from the school science. They expatiate that scientific concepts used in school are abstract, idealised and focused more on the textbook world and other printed documents. Thus, students might find it challenging to link the classroom science to their environment experiences in order to make sense of the intended learning topic. In addition, Rennie (2011) argues that there is a boundary between the school science knowledge and the science in the community.

Roschelle (1995) further revealed that learners are more likely to construct an interpretation that agrees with prior knowledge, and consequently disagrees with the viewpoint of the teacher. Hence, the effects of prior knowledge require a change from the view that learning is absorption of transmitted knowledge, to the view that learning is conceptual change. It is further emphasized that prior knowledge is properly understood not as the raw material that conditions all learning (Roschelle, 1995). As a result, Roschelle, (1995) opines that teachers should comprehend how prior knowledge affects learning in order to assist learners to make use of new experiences. It is the role of the teacher to clear the misconceptions and non-scientific beliefs learners bring to school (Meyer, 2004; Roschelle, 1995).

One of the factors affecting learners' understanding is the language of instruction. In the next subsection, I thus discuss how the language of learning and teaching (LoLT) influences sense making in science classrooms.

2.5.2 How LoLT influences learners' sense making in science learning

The medium of instruction in Namibian Education curriculum is English as from Grades 5-12. The Ministry of Education (2010) outlines that English is a compulsory medium of learning from Grades 4-12, while in Pre-grade to Grade 3 mother tongue is used as medium of learning.

Vygotsky (1978) emphasizes the role of language in the development of understanding, explaining that language accommodates a medium for learning. This basically means learning can take place in a social context and helps the child to construct a way of thinking. Furthermore, Vygotsky (1978) identifies language as the most important psychological tool in mediation of learning. He indicates that language enables learners' external experiences to be organised into thought. Vygotsky (1978) further claims that language is the medium through which concepts are acquired into mediation of

learning. In support, MoE (2010) states that language is the most essential tool for all communication and learning, perceived to be integral to every person's identity and it is the core of culture.

Lemke (1990) expresses that language is used in school to communicate and construct meanings in science. He believes that to talk scientific specialised language for reasoning and problem-solving-solving enables learners to make sense of science. However, this could be challenging especially in the Namibian context, whereby learners are English second language speakers. This is supported by Kocakulah, Ustunluoglu and Kocakulah (2005) that the language process serves as a vehicle for understanding academic content and learners who study main courses in a foreign language have difficulty connecting new and old information meaningfully. In support, Zhang (2008) highlights that language as a medium of classroom learning and teaching, plays an important role in enabling learners to construct knowledge. Learning cannot take place in the absence of language. Through language, the construction of meaning can be made for the understanding of concepts. Teaching science in English to learners who are second language speakers of English is quite challenging and in most cases it may lead to poor academic performance.

To this end, Probyn (2004) argues that learners should understand the English language first before they can make sense of scientific concepts meaningfully. Then, learners should be able to define the scientific concepts and demonstrate such understanding as well as be able to apply the learning concepts in real life situations. Furthermore, Probyn (2009) expresses a concern that classrooms become places where tensions and conflicts around language policy and practice are most acutely experienced and teachers are faced with complex pedagogical dilemmas. Learners have double problems as they are struggling to understand science contents while at the same time are struggling to learn English language. He reveals that English as the language of learning and teaching (LoLT) is actually creating a barrier to learning and academic access.

Cummins (1986) distinguishes between two kinds of language proficiency; Basic Interpersonal Communication Skills (BICS) and Cognitive Academic Language Proficiency (CALP), to explain the kind of language necessary for academic achievement. Cummins (1986), further explain that CALP is a kind of language which is cognitively demanding and disembedded from any context and is usually abstract in nature. He continues arguing that, unlike BICS, CALP takes place longer to develop and can only be achieved when first language works interpedently with the second language which is being targeted. CALP is the type of language proficiency required to read printed materials such as textbooks and to participate in academic dialogue and debate as well as written responses. In the same vein, Kamini (2001, p.5) states that, "the differences in grammatical and reasoning patterns

between everyday- and scientific language often act as barriers in learners' construction of meanings". The differences between science language used in schools and everyday language could be one of the factors constraining sense making in learning science.

Noordin and Yong (2009) argue that most learners who are English second language speakers do not have the necessary tools to make sense of advanced science concepts. As a result, they experience problems in making sense of the instructions for activities, experiments and some of the questions in examination papers. In writing their responses, they sometimes spell science concepts incorrectly, which can result in a meaning different to what they intended. For example, if a learner spells '*reflation*' instead of '*reflection*', then the meaning is different from what she/he intended to respond and it does not make sense in that context.

Lemke (1990, p.11) cautions that "the assumption that English Second Language (ESL) learners already understand what a concept means because they have learned the concept in first language cannot be taken for granted". In support, Kamini (2001) expresses that prior knowledge of concepts in the learners' first language is not directly transferred to English as second language.

Practical activities can be one of the teaching strategies to enhance sense making in the science classrooms for the learners to have empirical evidence to prove their hypotheses and correct their misconceptions. Thus, in the next section I discuss the role of practical activities in the learning and teaching of science.

2.6 Practical activities in the science teaching

Millar, Marechal and Tiberghien (1998) define practical work in science teaching as teaching and learning activities which engage students in handling or observing real object or materials that can enhance learning. Similarly, Maselwa and Ngcoza (2003) explain practical activities as 'hands-on', 'minds-on' and 'words-on' learning tasks. Likewise, Millar (2004) refers to a practical activity as any teaching and learning activity which at some point integrates the learners in observing or manipulating the objects and other resources they are studying.

Teaching of science thus requires practical activities to prove the scientific theories and enhance learners' participation in the learning of content. It is due to that, that Hodson (1990) stresses that practical work can serve as a vehicle for arousal of learners' interest and curiosity. In the same vein, Parkinson (2002, p.114) states that "learners enjoy practical work and that they learn through seeing things happen".

According to Millar (2004, p.20), “practical work is an essential component of science teaching and learning, both for the aim of developing students scientific knowledge about science”. In addition to that, practical activities enable learners become exposed to manipulating apparatus and thus acquire manipulative and observation skills (ibid). Millar (2004) continues to explain that practical work can take place in the laboratory as experimental work, but it can also take place without laboratory equipment. Roberts (2004) classified practical activities into five different categories that include skills practical, observation, technological, investigations and exploratory tasks. Through practical activities learners would be able to create a link between practical work and observed scientific process as it is supported by Millar (2010, p.2) who commends that “practical work helps students to develop their understanding of science, appreciate that science is based on evidence and acquire hands-on skills that are essential if students are to progress in science”. It means that, experiments can be used as a supporting evidence to confirm the presence of certain chemicals(s) in a substance(s). It is for these reasons that science is regarded as a reality of nature that can be confirmed through scientific experiment.

It is accentuated that as learners do experiments, ideas are modified and refined and so are shaped towards a shared set that makes discourse and collaborative action possible (Millar, 2004). It could be argued that practical activities may avoid rote memorization in learners because they make learners remember better when engaged in practical work.

Practical work enables learners to develop skills including improvising of apparatus to be used, handling of tools, observation, measuring, recording data and writing up the conclusions. Mukwambo (2012, p. 36) expresses that “some properties of practical work are; it is a medium of communicating ideas and can be achieved graphically, pictorially or symbolically”. Practical activity has a social constructivist’s character as it allows learners to interact with each other while the teacher is facilitating the session. Furthermore, it emerged from Mukwambo’s (2012) study that the science ideas emerged from the experiment are discussed by learners in concepts map and mind maps in establishing science evidence they would have found.

It is expressed that practical activities can bring changes in helping learners to know the environment and other natural phenomenon through learning and teaching discourses (Millar, 2004). In the same line of thought, Mukwambo (2012) stressed that learners develop scientific habits of mind as they use practical activities which are the tools of scientific enquiry. They ask questions and analysis of information and in this way it would lead to them to engage in those habits of mind mentioned.

Maselwa and Ngcoza (2003) confirm that practical work encourages learners at various stages of inquiry to predict explain, explore, observe and explain (PEEOE) particularly when learners have freedom to direct and adapt the activities according to the questions which emerge from their own experiences. This means that the PEEOE approach could help learners to develop scientific concepts of a specific topic so as to make sense of science in general. It is thus suggested that learning science should involve seeing, handling and manipulating real objects and materials and that teaching science will involve the act of showing as well as of telling.

Woodley (2009, p.50) indicates that “when done well, practical work can stimulate and engage students learning at different level, challenging them mentally and physically in ways that others science experiences cannot”. Science is a practical subject that requires learners to use their hands and minds to draw the conclusion based on concepts, projects or problems to be solved.

Ramsden (1994) states that for curiosity to be aroused and stimulated, there is a need for the teacher to position activities and experiments in the context of everyday life experiences of learners. Hence, the practical work enquires learners’ prior experiences (ibid). Apart from that, Oloruntegbe and Ikpe (2011) express that if learners do not see science as a real-life experience, they are likely to experience difficulty and challenge in learning science and become disenchanted with studying it. Thus, practical activities can motivate learners to develop the sense of ownership of the science subject.

It was advised that when approaching the end of any activity, teachers should facilitate the process whereby learners design their own representation of the underlying concepts of the experiment that can be done in simple way such as ‘mind maps’ and ‘concepts maps’ (Maselwa & Ngcoza, 2003). Similarly, Zion and Slezak (2005) claim that the role of a teacher during practical activities is to display flexibility, innovation as well as allocating time to the learners and encourage them to be proactive in the activities.

Pea (1993) states that if the aims of the practical work are precisely and clearly stated to the learners in a conducive learning environment, practical works can attract learners’ attention to learn better. Similarly, Woodley (2009, p.50) illustrates that in “planning an activity, the task should be tailored to achieve the identified aims, for example through discussion between students”. In addition to that Woodley (2009) further indicated that proper planning may improve the effectiveness of practical activities to meet particular aims. In the same light of though, Millar (2010) outlines that the starting point of a designed practical activity is the learning objectives that the teacher had in mind, and it is what the students are intended to learn from the activity.

According to Woodley (2009, p.49), “most practitioners would agree that good-quality practical work can engage students help them to develop important skills, help them to understand the process of scientific investigation and develop their understanding of concepts”. In addition, Woodley (2009) further states that really effective practical activities enable learners to construct a bridge between what they can see and handle (hands-on) and scientific ideas that account for their observations (brains-on).

When learners design a model or carry out scientific projects or investigations may help them to improve their cognitive and creative skills. Other importance of practical activities in science teaching as expressed by Millar (2010) are:

- To encourage accurate observation and description;
- To arouse and maintain interest;
- To make phenomena more real; and
- To promote a logical and reasoning method of thought.

Hodson (1990) further claims that practical activities improve acquisition of laboratory skills; therefore teachers must focus on skills which allow learners to be engaged in useful activities.

Despite all the above mentioned uses of practical activities during teaching and learning in science classrooms, there are however, have some weaknesses.

In this study practical activities were applied through ASEI lesson interventions. Hence, in the next section I discuss ASEI-PDSI as a teaching approach in which practical activities are being integrated.

2.7 ASEI-PDSI as a teaching approach which integrates practical activities

Changeiywo, Ng’eno and Barchok, (2013) call for the Strengthening of Mathematics and Science and in Secondary Education (SMASSE) project in the study conducted in Bomet and Kenya. This is in partnership between the government of Kenya and the government of Japan through Japan International Cooperation Agency (JICA). The SMASSE project introduced the Activity, Student, Experiment and Improvisation (ASEI) movement which is geared at making learning student-centred as opposed to teacher-centred. In order to achieve the ASEI conditions SMASSE, Changeiywo et al. (2013) introduce the Plan, Do, See and Improve (PDSI) approach to teaching and learning. PDSI is the planning of lessons with hands-on and minds-on activities for the learners which are then assessed to see the success and failures of the lessons.

Gathumbi, Hintze and Mungai (2013) affirm that ASEI-PDSI approach is a learner-centred lesson which is based on constructivist theory with the aim of engaging learners in the learning process. In this study, an ASEI-PDSI approach was adapted and used as a teaching approach that can influence sense making of the topic light. Changeywo et al. (2013, p.247) state that “ASEI-PDSI is the approach informed by constructivists who believe that an education program that allows learners to be motivated, critical thinkers, problem solvers and meta-cognitionists will allows them to take ownership of the learning process”.

ASEI is the shift from chalk and talk to learners’ activity-oriented learning with the focus on meaningful activities (Rotich & Mutisya, 2013). ASEI lessons provide a bridge in order to relate and integrate practical activities with theoretical knowledge as learners find themselves observing, questioning, hypothesizing, predicting, interpreting and communicating (ibid). However, the PDSI approach targets the teachers and emphasis on early preparation of the lesson, ensuring that the lesson is conducted effectively and making necessary improvement.

Changeiywo et al. (2013, p.247) assert that the “ASEI principle is based on the fact that students do not simply copy the science world; rather, they construct their own meaning of it”. With the ASEI-PDSI approach, students are to be provided with opportunities to construct scientific knowledge through the interaction of their observations, prior knowledge and mental processes (Changeywo 2013). Changeiywo et al. (2013) also noted that human beings have the ability to construct knowledge in their own minds through the process of discovery and problem solving. This means that ASEI-PDSI is informed by both cognitive and social constructivism .This is detailed in the Section 2.7 Furthermore, Rotich and Mutisya (2013), point out that ASEI-PDSI is possible development in science as it has given students opportunities to explore and satisfy their curiosity.

Agreeing with this statement, Gathumbi et al. (2013, p.7) state that “in a typical ASEI-PDSI lesson, the teacher is expected to plan for Activities/experiments that will create opportunities for students to learn intended concepts, acquire needed skills, and in the process enjoy learning the subject”. It was further stated that through ASEI-PDSI approach, formal assessment is a model for consistent performance and measuring learners’ progress (Gathumbi, 2013). It is due to this reason that after ASEI lesson interventions, followed with a post-test were administered to the learners to evaluate how SEI-PDSI approach influenced sense-making of the topic light among learners.

ASEI-PDSI approach is more or less similar to the Namibian learner-centred lessons. However, the ASEI-PDSI approach makes provision for teachers to state the rationale of the lesson objectives and competencies for the learners to know the purpose of learning that specific topic. Despite the benefits

of ASEI-PDSI as discussed above, some teachers complained that the implementation of learner-centred pedagogy demand more teacher time and its full application would slow down the coverage of syllabus (Gathumbi et al., 2013). Apart from time constraints, it is noted that it requires enough teaching and learning aids to enhance practical activities and sometimes schools do not have them all (ibid). It is precisely for these reasons that the ASEI-PDSI always makes provision to improvise learning aids using easily accessible and local available materials.

It is appreciated that ASEI-PDSI teaching approach is based on constructivist theories of learning which had its roots from cognitive psychology place the learner in an active role of knowledge construction (Changeiywo et al., 2013). In addition, this approach creates opportunities for learners to apply their prior knowledge about the subject content based on their personal experiences, schooling and social interactions (Changeiywo et al., 2013). It constitutes both cognitive and social constructivism theories.

In the next section, I discuss the theoretical framework which informed this study in order to provide answers to the research questions.

2.8 Theoretical Framework

This study is informed by the constructivist perspective of learning. Constructivism is the belief that meaning is constructed and not discovered (Gray, 2000).

Atherton (2009) defines constructivism as a set of assumptions about the way human beings learn. Constructivists believe that knowledge is constructed when learners are actively engaged in the learning activities, and they thus suggest a move away from the notion that knowledge is given to the passive learners (Atherson, 2009).

Drawing from constructivism, Okere (1986) suggests that learners approach a domain of knowledge with some prior knowledge about the learning content constructed from personal experiences, schooling and social interactions. According to Moll (2002, p.11), “constructivism or constructionism or indeed any term for the construction of knowledge does not have, nor should it have, only one particular meaning”. This study is thus informed by both cognitive and social constructivism as a theoretical framework in which I explored how learners make sense of the topic light through ASEI-PDSI teaching approach.

2.8.1 Cognitive constructivism

Cognitive constructivism is a Piagetian learning theory focusing on learners' mental cognitions and looking into how learners develop or construct a mental model of their worlds (Bruner, 1961). I find cognitive constructivism useful to my research because it describes how learners make sense of science that might be influenced by individual intellectual abilities and social interactions.

Bruner (1957) points out that thinking is the primary outcome of cognitive development resulting from new learning experiences of intelligent mind. It means that individual learners can think on their own and are able to discover new information influenced by their intellectual abilities. Based on his understanding on human psychology, Bruner (1960) argues that as active constructors of their own knowledge, children are more capable of understanding complex information. Furthermore, Bruner (1960) posits that human beings learn through three modes of representation: enactive (actions-based); iconic (visually-stored images or mental pictures); and symbolic (language-based in words and symbols). This suggests that through the experiment-based teaching intervention, learners can make sense of the learning contents through those modes of representations as they are incorporated in the lessons.

Constructivist's perception is that an education program that allows learners to be motivated, critical thinkers, problem solvers, and meta-cognition may allow them to take ownership of the learning process (Changeiywo et al., 2013). As a result of this perception, the ASEI principle is that students do not simply copy the world; rather they construct their own meaning of it. That is, learners should be given opportunities to construct scientific knowledge through their observation, prior knowledge and mental processes.

2.8.2 Social Constructivism

Social constructivism was originally founded by the Russian psychologist, Lev Vygotsky. According to Vygotsky, children are at their highest peak of learning when they are collaborating with more knowledgeable partners (Vygotsky, 1978). Furthermore, it is believed that learners learn scientific concepts better through social collaboration with other knowledgeable individuals rather than through direct instructions (ibid).

In addition, Moll (2002) discusses social constructivism as a learning theory which emphasizes that learning occurs as a result of social interaction with a knowledgeable individual. Furthermore, the social constructivist theory explains how knowledge is being constructed by learners through social interaction with the community, family members at homes, teachers and fellow learners. Learners are believed to be at the centre of learning (Moll, 2002).

Wertsch (1985) explains that through social constructivism the more knowledgeable others help the learners by intellectually scaffolding them, and enable learners to carry out complex tasks than when they are on their own. In this study, through the ASEI teaching intervention learners were provided with guidelines on practical activities. The guidelines were intended to enable learners to identify scientific concepts that emerged from each lesson through sketching the concept maps. After being helped by the teacher (more knowledgeable other), learners might be able to carry the learning tasks individually and this, according to Vygotsky (1978) is referred to as the Zone of Proximal Development (ZPD). Vygotsky (1978) describes ZPD as the distance between the development as determined by independent problem solving and the level of potential development as recognised through problem solving under adult guidance or in collaboration with more capable peers.

In Vygotsky's conceptualisation of the ZPD, the word proximal, meaning 'coming' next, supposes an impression of what can potentially happen. What the child does independently when involved in a task reveals what that child knows and can do today without assistance – the development that has already taken place. Potential refers then to what the child may be able to do with help or through interaction with others (Stott, 2016, p.26)

Vygotsky (1978) revealed that scientific concepts are not just learnt through direct instruction, but they can be learnt through collaboration. Sense-making can possibly be made when learners interact with each other, with teachers and with their community.

In reviewing the ZPD, Stott (2016, p.32) revealed that:

Learning and development can take place through collaboration with peers and adults, through play, role-play and imitation, through mediation with adults and peers and through the use of tools and semiotics such as dialogue and non-verbal communication.

As espoused by McRobbie and Tobin (1997), individual learners are able to make sense of the learning activities through social interactions. They assert that in the social constructivism learners should have control over their own learning and be able to construct meanings from their experiences in terms of what they know at the time of learning. It could thus be argued that learners' prior knowledge and home background experiences are some of the factors informed by social constructivism and can be used by the teachers to explore how learners make sense of learning science topic(s). In the same vein, Moll (2002) asserts that social constructivism recognises learning as an active process involving learners in tasks associated with making connection between their experiences and existing knowledge. One should understand that learners can make sense of the

classroom content by relating it to their existing knowledge acquired from the previous grades or home experiences.

In the context of this study, a classroom served as the social platform in which learners were learning through interacting with their teachers and fellow learners to make sense of the topic *light* in particular. With the topic light, for example, learners should be able to expand their prior knowledge about light with the new content introduced in the classroom. Learning concepts of the topic light requires learners to have prior knowledge in most of the concepts around the properties of light such as reflection, refraction, absorption and formations of images by mirrors and lenses and applications of properties of light in everyday life.

From a different angle, McRobbie and Tobin (1997) argue that social setting may constrain learning as the action of others shape individual learning. They put forward that the application of social constructivism ideas can be limited by the time, focusing more on examination passing and influenced by the teachers' beliefs. Although there are few shortcomings identified in the application of constructivism, I still find this theory relevant to this study in providing the lens to understand how learners make sense of the topic *light*.

Both cognitive and social constructivism were useful and applicable to this study because the research questions focussed on learners' sense-making, prior knowledge, experiences, conceptions and conceptual understanding of the topic light.

2.9 Concluding remarks

In this chapter I discussed the relevant literature that informed my research study. The chapter covered literature on Namibian science curriculum, learners' misconceptions of the topic light; learners' every day prior knowledge, learners' sense making, practical activities in science, ASEI-PDSI teaching approach and the theoretical framework.

In the next chapter, the research methodology is discussed.

CHAPTER THREE:

RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This research was a Namibian case study which focused on one urban secondary school. The research design shaping this study is discussed in this chapter.

In this chapter, I thus describe the methodological framework that guided my research process. I describe and discuss the reasons for choosing an interpretive paradigm and mixed method approach (qualitative and quantitative) to address my main research question and sub-questions (Section 1.5). The data gathering techniques, the sampling of participants and how the data were analysed is also detailed.

Furthermore, I discuss issues regarding validity and trustworthiness, ethical considerations and limitation of the study. The chapter ends with some concluding remarks.

3.2 Research design

According to Bertram and Christiansen (2015, p.40), “the research design is a plan of how the researcher will systematically collect and analyse the data that is needed to answer the research question”. In the context of this study, the research design incorporated the theoretical framework on which the study was built, specifically cognitive and social constructivism.

Cohen, Manion and Morrison (2011) describe research design as it clearly illustrates the overall purpose, methodology, types of the data needed, data collecting methods and data analysis techniques of the research study. The research design helped me to access deeper insights into the research study through interpretive paradigm.

3.2.1 Interpretive research paradigm

The aim of interpretive research is to offer more explanations of the events, or where necessary, to develop some explanations for it (Cohen, Manion & Morrison, 2010). Furthermore, it is stated that the interpretive research paradigm is characterized by being subjective, studying people in their natural settings and having multiple interpretations (Cohen et al., 2010). This suggests that through the interpretive paradigm there is no one single conclusion and deductions are made based on the generated data to draw meaning.

Interpretive research paradigm enables the researcher to understand the meaning that people give to their own social interactions through listening to their voices and observation of their actions

(Bertram & Christiansen, 2015). In the setting of this study, this paradigm looked into learners' sense-making of the concepts in the topic light. The use of an ASEI-PDSI teaching approach helped me to explore how learners were making sense of science concepts through practical activities and incorporation of their prior knowledge during the teaching interventions.

This paradigm further enabled me to explore how learners use their prior knowledge as a starting point to construct abstract ideas by sketching concepts maps of scientific concepts that emerged from every lesson intervention. As part of cognitive development, the process of constructing ideas develops the tendency to internalise concepts or new ideas. Through the ASEI teaching intervention, learners were able to do the practical activities in groups and helped each other in constructing meaning to make sense of the concepts as part of their ZPDs in social constructivism (Vygotsky, 1978; Stott, 2016). These developmental processes that enable learners to make sense of the concepts are founded through the interpretive paradigm, hence this study took the nature of a case study.

3.2.2 Case study on learners' sense making of the topic light

A case study is known as an intensive description and analysis of a phenomenon or social unit such as an individual or group (Merriam, 2002). Similarly, Merriam (2009) defines a case study as an in-depth description and analysis of a bounded structure. Thus, a case study allows the researcher to catch the complexity and situations of the behaviour, presents and represents reality to give a sense of being a witness of the situation (Cohen et al., 2011). Similarly, Bertram and Christiansen (2015, p.42) define case study as an "in-depth investigation of a specific group of people in a given context". Thus, in case studies, researchers tend to specifically focus on a particular case; as it is indicated by Leedy and Ormrod (2010) that this could be due to the case under study with the understanding of informing the current educational practices.

My research was a case study of one secondary school in a Namibian urban area (see Section 3.3). The case study of 22 Grade 11 Physical Science learners was undertaken, the investigation being how they made sense of the topic light through ASEI teaching approach. In addition, the study explored how cognitive and social constructivism as theoretical frameworks may influence learners' sense-making of light concepts.

Hodkinson and Hodkinson (2001) state that case studies reveal more real life and bring out substantial issues that the researcher might not have expected when starting the journey of the research process. It means that through this study a researcher might learn new things that were not part of the hypothesis. Although it was a mixed method case study, Creswell (2003) posits that qualitative case study creates opportunities whereby the researcher directly works together with the participants. It is

through qualitative case study that the researcher could understand the problem in a real life setting through observing and listening to the *voices* of the participants on the ground.

Given that this was a case study with a specific focus, the aim of the research was to study only 22 Grade 11 Physical Science learners (see Section 3.3). The purpose was to access deeper insight into the learners' sense-making of light concepts based on their thoughts, prior knowledge, experiences, explanations, reasons and conceptual understandings. Thus, this study focused on qualitative approach more than the quantitative approach with regard to data analysis and interpretation.

The research process targeted how the ASEI teaching approach influenced learners' sense making through active engagement of learners in the practical activities. That brought the study into the learners' context whereby meaning making developed from every day prior knowledge to school science. It is based on that, that Bassey (1999) highlights that a case study uses context to gain in-depth understanding of participants' thought processed and meanings.

In the context of this study, learners accessed sense-making whilst I accessed data. It is referred to as a mutual benefit between the participants and the researcher. Through the ASEI teaching intervention, learners' thoughts or ideas were constructed on existing schema and experience which linked this study to cognitive and social constructivists approach. As this was a case study, when teaching intervention took place, social interaction took place as well. In this context, learners were carrying out practical activities in groups and shared ideas. However, a re-test and a post-test were completed individually to obtain individual learners' sense making of the content in the concepts of *light*.

Making sense of the learning concepts around topic *light* was at the heart of this case study. Learners' thoughts and ideas on the concepts of the topic were accessed through data sources. However, some data sources such as questionnaires, observations and stimulated-recall interviews were used to make some of the findings clearer and without losing its nature as this was a qualitative case study. In addition, the data gathered from learners' pre-test and post-test scores is presented in the form of tables and graphs which represent the nature of quantitative approach (see Chapter 4). The different methods of data presentation indicated that qualitative and quantitative approaches were used to interpret gathered data.

Foss and Ellefsen (2002) claim that, both qualitative and quantitative approaches can enable a researcher to obtain a true representation of reality in order to address various aspects of knowledge. Similarly, Johson and Omwuegbuzie (2004) support that qualitative and quantitative approaches can be applied to supplement each other, as in a 'mixed method' design.

3.2.3 Mixed method design

This was a mixed methods case study and sought to investigate how Grade 11 Physical Science learners make sense of the topic light through the ASEI-PDSI teaching approach. This is the method approach proposed by Harris and Brown (2010), that it allows the researcher to present, analyses and discuss responses to confirmatory or exploratory questions. In the same vein, Christensen, Johnson and Turner (2015, p.392), define mixed-methods research as “a research approach in which quantitative and qualitative data or techniques are combined or mixed in a single research study”. Furthermore, it is appreciated that mixed-method approaches enable the researcher to use various sources and methods of data collection in order to ensure validation of data.

In the context of this study, I used the quan→QUAL design as it is highlighted by Christensen et al. (2015). According to Christensen et al. (2015), the quan→QUAL design represents that this mixed method is a qualitative priority where a greater emphasis is placed on the qualitative methods and quantitative methods are used in a secondary role.

In this study, the data collected to answer Question One are both qualitative and quantitative. The first question of this study is about the learners’ conceptions and experiences of the topic light (see Section 1.5). Thus, a questionnaire with open-ended questions was used as a tool to collect data for this question which learners provided their thoughts, ideas and experiences. The learners’ mark scores from the pre-test determined their level of experiences or prior knowledge of the topic *light*.

The data collected to answer research Question Two are both qualitative and quantitative. Question Two is about learners’ conceptual understandings of the topic light (see Section 1.5). In this context, data from a pre-test and a post-test were used to answer this question. Hence, the learners’ scored marks from both tests were quantitatively analysed, presented and discussed while their explanatory answers were qualitatively analysed, presented and discussed.

The data collected to answer Question Three of this study was qualitatively analysed, presented and discussed. Question Three is about factors that enable or constrain learners to make sense of the concepts of light (see Section 1.5). Thus, observation of the video-taped lesson and stimulated-recall interviews were used as tools to collect these qualitative data sets.

Ramasike (2016, p.36) highlights that “different data sources in the mixed methods design enhance the validity of the study, the complementary of data, development, initiations, explanation, sampling, contextualisation, illustration and processing results”. Thus, in this study, graphs and tables were used to present and compare learners’ scores from pre-test and post-test in order to evaluate the influence

of ASEI lesson interventions on learners' sense-making of the concepts of light. In addition, data from questionnaires, observations and stimulated recall interviews were used to investigate how learners were making sense of the concepts around the topic light. The purposive sampling was used in this case study and participants were selected to form up a focus group.

3.3 Research site and Participants (sampling)

In a qualitative research the choice of a research site should help the researcher understand central phenomena (Creswell, 2008). It means apart from the stories and explanations that people put forward regarding their conceptions, perspectives and experiences, the researchers are also interested in the way they themselves attend to the process of obtaining information (Hesse-Biber & Leavy, 2005).

I used convenience and purposive sampling to select one of the secondary schools in the Ohangwena Region in the northern part of Namibia. Cohen, Manion and Morrison (2007) define convenience sampling as a method whereby researchers have options to choose the sample based on those whom they have easy access to. Furthermore, Cohen et al., (2011) outline that purposive sampling is likely applicable to qualitative research in which research participants are chosen for intended specific reason. More so, Creswell (2012) indicates that convenience sampling focuses on selected individuals due to their easily availability and accessibility.

I thus chose this secondary school because it is closer to my duty station in terms of distance and accessibility. This is an urban school situated within the border of Helao Nafidi Town and it offers curriculum from Grades 8 to 12.

The school has a population of about 900 learners from Grades 8 to 12 and 30 teachers. The school has one laboratory for Physical Science and another one for Biology. In addition, the school has learning and teaching support materials (LTSMs) that can be used in the classrooms or laboratories to carry out the practical activities. Although the school has some science LTSMs, I also provided learning materials that were not available at school to be used during the teaching intervention.

This chosen school is one of the best performing schools in Ohangwena region as it has been performing well consistently for three consecutive years, scoring a 90% and above pass rate in Grade 10 Physical Science examinations for the last three consecutive years (2013, 2014 and 2015). To protect the identity of the school, I called it Z secondary school (pseudonym)

At this school, I selected one of the Physical Science teachers whom I engaged in the preparation and teaching of the lessons that I subsequently observed. The Physical Science teacher who was my

research assistant was also asked to choose his own pseudonym and he called himself Mr B. The research assistant, or Mr B, has a record of excellence in Physical Science JSC and NSSCO level examinations in the past eight consecutive years (from 2008 up to 2015).

The research was conducted with a Grade 11 class of 22 learners. I opted to carry this research study in the Grade 11 classroom because learners have a background of the topic light from the Grade 10 curriculum so that I could be able to get their conceptions, experiences and prior knowledge of the topic. All the research activities were carried out in the afternoons after the normal teaching hours to avoid interrupting with the normal school teaching schedule.

Only 22 out of 42 learners whose parents signed and returned the consent letters were engaged in this study. Parents thought that their children need to rest in the afternoon. Thus, the data analysed in this study is based on the number of learners whose parents signed the consent letter. All 22 participating learners managed to attend the whole research process (from questionnaire up to the post-test) and they were highly committed. After administering of the pre-test, three learners were selected for one-one stimulated-recall interviews based on their scores and responses. They were categorised as high (56%), average (38%) and low (16%) score. Those learners provided interesting answers that were both scientific and non-scientific. Therefore I wanted to get further explanations as how they were making sense of their answers.

After every lesson intervention, a focus group stimulated-recall interviews with all 22 learners were conducted for further probing on learners' actions, answers, behaviours and explanations during the lessons. This was done while I we were watching the videotaped lesson together with learners. The purpose of this SRI was to obtain deeper insights on how they were making sense of the lesson contents by providing explanations on their actions that were not caught up well during lesson observations.

3.4 The teaching intervention

Three ASEI lessons were designed by Mr B (pseudonym) together with me to enable me to explore how learners made sense of the topic light (see ASEI lesson plans 1-3 in Appendix E). Each lesson lasted for about 45 minutes. Lesson 3 was a double period of about 90 minutes. All lessons were delivered by Mr B with following various steps as indicated below:

ASEI Lesson 1 (45 min)

Lesson Topic: Reflection of light

Step1: Mr B started the lesson by asking learners to discuss briefly how light enables our eyes to see things around us. He further asked them to state the phenomenon whereby light enables eyes to see things.

Step 2: In this step, learners (in 5 groups of four) were provided with the plane mirrors to do the following observations:

- (a) Characteristics of image of a cup in the mirror; and
- (b) Closing their left eyes and observe their images in the mirror

These practical activities were done to enable learners to make sense of the characteristics of images in the plane mirror. Apart from practical activities, learners were further asked to make sketched drawings indicating how the reflection of light enables their eyes to see the image of a cup in the plane mirror. This activity was designed to explore how learners make sense of the concepts through observation and their drawings confirmed whether they were making sense or not.

Step 3: The classroom was darkened by switching off the light bulbs and the windows and door were closed with fitted curtains. Learners were provided with torches and asked where to aim the torch flash if they wanted to see the image of the yellow sticker placed on their chests in the plane mirror.

In step 4, the teacher asked learners individually to state the applications of reflection of light in everyday life. This activity was intended to explore how learners make sense of the topic *light* by linking the classroom science to their everyday life experiences as proposed by Oloruntegbe and Ikpe (2011) as well to develop the conceptual understanding of the reflection light. At the end of this lesson learners were assessed by Mr B, who asked them to draw concept maps showing all scientific concepts that emerged from lesson topic ‘reflection’ of *light*.

ASEI lesson 2 (45min)

Lesson Topic: Refraction of light

Step1: The teacher introduced the lesson by linking it to lesson one (reflection of light). In the introduction, he provided learners with the following objects: piece of wooden plank, silver plate, and a mirror. He asked learners to state which of those objects are able to reflect light rays and they should explain their answers. This practical activity was designed to evaluate the learners’ prior

knowledge and to identify whether learners know that all objects are able to be seen due to the reflection of light.

In step 2, the teacher provided learners with bowls of water to observe their images and explain the phenomenon that generates their images in water. This activity was demanding the learners to relate the surface of water with that of the mirror as both generate image with similar characteristics.

In step 3, the teacher provided learners with containers of clean water and coins. Learners observed the coin in the container without water and later they added water and observed the coin in the water. Learners were expected to explain their observations in terms of the image positions and its depth.

In step 4, Mr B asked learners to sketch the diagram with arrows to show how the rays of light travel from the coin under water into their eyes.

In step 5, Mr B asked learners to compare the density of water with that of air and how it affects the speed of light that result on the refraction of light.

In step 6, the teacher provided learners with convex lenses and let them go outside to observe how they affect the rays of light from the sun. In their groups learners were expected to report on findings of their observations and give their reasons.

In step 7, Mr B asked learners to explain the properties of image formed by convex lenses based on their observation from step 6.

In step 8, Mr B defined the vacuum as an empty space. He then asked learners to explain why light travels faster in the vacuum than in other mediums.

In step 9, learners were asked to draw a concept map showing all the scientific concepts that had emerged from this topic refraction.

At the end of this lesson, Mr B read the rationale of lesson. He explained, “*The refraction of light is important in our life as it can be applied in eye spectacles to correct eye defects and in many other industries*”. The purpose of reading the rationale was to enable learners to recognise the need for learning such a topic.

ASEI lesson 3 (90 min)

Lesson Topic: This lesson was about the continuation of reflection of light

In step 1, Mr B introduced this lesson by placing white, blue and black papers on the classroom wall and asked learners in their groups to find out which one of those papers can be easily seen and explain why and how. The purpose of this activity was to explore learners' sense-making with regard to colours that reflect more light than others.

In step 2, learners were provided with a reflector jackets and were asked to discuss in groups why reflector jackets are used by people in industries such as mining, transport, construction and fishing. The purpose of this activity was to explore how learners linked the topic *light* to the uses and importance of reflection of light in everyday life.

In step 3, individually, learners were further asked to list other sectors apart from mining, transport, construction and fishing, where clothes with reflectors are being worn and why.

In step 4, learners, in their groups, placed a pencil in front of the mirror on the table. The pencil remained fixed and learners moved a little further from the mirror. The teacher asked learners to explain what happened to the location of the image of the pencil in the mirror. In this activity, first learners were expected to predict their answers before the practical activity.

In step 5, the room was darkened; the lamp was raised a little higher. The pencil in front of the mirror remained fixed. Learners were asked to predict before the experiment and later to explain after the experiment what happened to the location of the image of the pencil in the mirror.

In step 6, the lamp was raised little higher. The pencil and the mirror remained fixed on the table. Learners were asked to predict before the experiment and explain after the experiment what happened to the height of the image of the pencil.

In step 7, the lamp and the mirror remained fixed; the pencil was moved a little further from the mirror. First learners were asked to make their predictions as to what would happen to the height of the image of the pencil in the mirror and later explain it after the practical activity.

In step 8, learners were asked to draw the concept maps showing all the scientific concepts that had emerged from this lesson. The purpose of this activity was to evaluate learners' science conceptual understandings.

At the end of this lesson, Mr B highlighted the rationale of the lesson. He stated that "*reflection of light is applied in industries such as mining, transport, construction, etc., for safety reasons*".

The ASEI lessons are in line with Bruner (1960), who posits that human beings learn through three modes of representation: enactive (actions-based); iconic (visually-stored images or mental pictures); and symbolic (language-based in words and symbols). The ASEI lessons integrate practical activities that accommodate all three modes of representation.

The data that emerged from the three ASEI lesson interventions are presented, analysed and discussed in Chapter 5 in this thesis.

3.5 Research Goal

The main goal of this research was to investigate how Grade 11 Physical Science learners make sense of the topic light through ASEI-PDSI teaching approach. To achieve this goal, the following questions guided the study:

1. **What are Grade 11 Physical Science learners' conceptions and experiences of the topic light before and after an ASEI-PDSI teaching intervention was implemented?**

To answer this question I administered questionnaires to 22 Grade 11 Physical Science learners. This was done in order to obtain their current conceptions, experiences, opinions, thoughts and feelings on the topic light prior to any new teaching intervention about the topic light. I also administered a pre-test to 22 learners in which they had to answer content-based questions about the topic light in order for me to explore their prior knowledge of this topic. In addition to the pre-test, I also conducted a simulated-recall interview with three individual learners that were chosen based on their responses from the pre-test as they presented three categories (highest, average and lowest score). The purpose of this interview was to get their sense-making of the topic through providing further explanations of their responses.

Table 3: Profile of learners selected for stimulated recall interview on pre-test responses.

Learner	Gender	Pre-test score (%)	Post- test score (%)	Pre-test category	Post-test category
Learner 1 (L1)	Female	16	66	low	high
Learner 2 (L2)	Female	28	56	average	average
Learner 3 (L3)	Male	56	75	high	high

2. How does an ASEI-PDSI teaching intervention influence Grade 11 Physical Science learners' conceptual understandings of the topic light?

To answer this question, I observed the ASEI-PDSI lessons which were videotaped as learners were engaged in the learning activities. As a researcher, I was responsible for video recording the lessons while Mr B was delivering the lessons. Those lessons were prepared by me together with Mr B at the school and were subsequently all delivered by Mr B. The purpose of the lesson observation was to explore learners' sense making of the topic light. I analysed the videos including the learners' practical activity worksheets and concept maps which were developed during the lessons. The concept maps were sketched by learners to present all the scientific concepts that emerged from each lesson intervention. This was followed by focus group stimulated recall interview focusing on learners' actions, behaviours, participations and reasoning during lesson. After the ASEI teaching the post-test was administered to all 22 learners to assess how it influenced them to make sense of the topic *light*.

3. What factors enable or constrain Grade 11 Physical Science learners to make sense of the topic light?

This question was answered through lesson observations and administering of a pre-test at the beginning of the intervention and a post-test after the intervention.

3.6 Methods of data gathering

The following data gathering techniques were used in this study:

- Questionnaires;
- Pre-test and stimulated-recall interview;
- Lesson observations, video-taped lessons and stimulated recall interviews; and
- Post-test.

I now discuss each of the data gathering techniques in detail.

3.6.1 Questionnaire

A questionnaire is a list of questions which the respondents are requested and expected to answer (Bertram & Christiansen, 2015). Questionnaires are a good data collection tool to use because one can use them to collect data from a large group of people (ibid).

In my context, I administered questionnaires to 22 Grade 11 Physical Science learners. In the questionnaire I used open-ended questions to obtain learners' prior knowledge, views, opinions and experiences of the topic light (see Appendix F). The advantage of open-ended questions is that they enable participants to provide explanations to questions something which helps to qualify their responses and avoid the limitation of responses (Cohen et al., 2011). Similarly, Bertram and Christiansen (2015, p.74) state that "open-ended questions allow the respondents freedom to answer a question in their own words in whatever way they think appropriate".

However, it was criticized that on the other hand open-ended questions can lead to irrelevant and redundant information as they may be too wide for the respondent to know what kind of information is being sought (Cohen et al., 2011).

3.6.2 Pre-test on the topic light

A pre-test is a method of testing whereby the researcher tests learners before the intervention to establish what they already know (Bertram & Christiansen, 2015). After the lesson intervention the post-test covering the same content as the pre-test was also administered to the same learners (see Appendix G).

In my study, the pre-test and post-test were adopted from John's (2014) four tier optics diagnostic instrument that was administered to students in her study conducted in South Africa. These instruments were adjusted and modified to suit the context of the Namibian NSSCO level Physical science curriculum.

The following changes were made on John's (2014) optics diagnostic test: in question one, an inverted copy of tall building in the lake was replaced with a figure showing an inverted image of the zebras drinking water in the lake in Etosha National Park of Namibia (see Figure 5, Chapter 4). This question was modified to make it relevant to the Namibian context. In the pre- and post-test it appears to be question two. In addition, questions were increased from ten to fifteen questions to cover more content of the topic light (see Appendices G & H).

I administered a content-based pre-test to 22 Grade 11 Physical Science learners to obtain their sense-making, prior knowledge, conceptual understanding, experiences, challenges and difficulties with regard to the topic light. 21 of the participating learners managed to complete all questions in the questionnaire within a given time even though most of them could not answer them correctly. However, one of the learners did not attempt to answer questions thirteen to fifteen.

3.6.3 Stimulated-recall interview (SRI) from pre-test responses

Fox-Turnball (2009) defines simulated recall interview as a method in which participants are prompted by visual recall to reflect back on the activity conducted by them previously.

Three learners were selected based on their pre-test results and responses for the follow-up individual interviews so as to probe more deeply their explanations. The three learners who were interviewed came from the following categories: the highest, average and lowest score of the test (see Section 3.3). During the follow-up semi-structured interviews, open-ended questions were used to explore prior knowledge, conceptual understanding, thoughts, opinions, experiences, skills and challenges related to the learning of the topic light. Johnson and Christensen (2004) define semi-structured interviews as a process in which selected participants are engaged on a one- to-one verbal dialogue in order to get detailed information.

3.6.4 Stimulated recall interviews (SRIs) from video-taped lessons

Lyle (2003, p.861) defines stimulated recall (SR) as “a family of introspective procedures through which cognitive process can be investigated by inviting participants to recall, when prompted by a video sequence their concurrent thinking during that event”. It is believed that SR is used many experimental and laboratory contexts and in a variety of forms as it is perceived to provide an opportunity to maintain the real life context (ibid). In the same line of thought, Beutel, McFadden, Nguyen, and Tangen (2013) define stimulated recall interview as a research technique in which participants view a video sequence of their behaviour and are then invited to reflect on their decision-making process during the video-typed event. It is further believed that SR gives participants a chance to view themselves in action as a means to recall their thoughts, ideas, behaviours and reactions as they occurred (Beutel et al., 2013).

In this study, I video-taped four lessons that were attended by 22 learners in which I acted as an observer and at the same time a video operator. I used one video-camera which I shifted from one position to another in the classroom while I was taking notes of what was happening in the classroom at the same time.

After each recording, I viewed the video and developed the interview questions based on individual learners' responses, actions and behaviours during the lesson. Although it was a group interview with 22 learners, probing questions were posed to specific individual learners to investigate how they made sense of lesson contents. The purpose of the interview was to allow learners to give further explanations and thoughts.

Gass and Mackey (2000) and Lyle (2003) emphasized that the researcher must avoid the time delay between the event and the SRI to increase validity of data. Thus, I conducted all the SRIs one day after the lesson was recorded in the classroom. Individual learners were asked verbal interview questions such as:

- What were your thoughts when you did it in this way?
- What were you thinking when you say this?
- What did you mean by saying this?
- Why did you say this?

During the SRIs the tape was replayed and stopped (interrupted) whenever it prompted the learner to remember something he/she had been thinking about during the lesson.

As the SR was focusing on individual thinking and reasoning in responding to the cognitive constructivism as part of the theoretical framework (see Section 2.7.1) of this study, I found it challenging that few individual learners could only provide further explanations such as '*I have no idea*', '*I just mean what I say*'. Thus, it is known that the use of SRI may cause the participants to produce answers in defence of their behaviours and to answer the questions in a way they anticipated the researcher would want (O'Brien, 1993; Lyle, 2003).

In addition, the quality of videos recorded in lessons three and four were poor in terms of pictures, although the sound was loud enough. Poor quality pictures were caused by interference of sunshine through the windows. The last two lessons were conducted in the Physical Science laboratory which was not fitted with window curtains, while the first two lessons were conducted in the Biology laboratory fitted with window curtains. The Biology laboratory was lastly occupied by Grade 12 Biology and Physical Science high level learners for the end of year examinations. Therefore, the first two lessons produced quality videos compared to lessons three and four.

These lessons were video-taped while the same time I was observing. Thus, I now look at lesson observations.

3.6.5 Lesson observations

It is believed that observation enables researchers to look afresh at the true behaviours and actions that might otherwise go unnoticed (Cooper & Schinder, 2001). According to Maxwell (1992, p.94),

Observation can enable you to draw inferences about the perspectives that you could not obtain by relying exclusively on interview data. It is of particular importance to get at a tacit

understanding and theory in use as well as aspects of the participants' perspectives that they are reluctant to directly state in an interview.

I observed three lessons that were presented by the Physical Science teacher. These lessons were planned by me together with the Mr B at school for me to ensure that the concepts around the topic light would be adequately covered in each lesson. The designed lessons were based on the ASEI-PDSI teaching approach (see Section 2.6) which was intended to create an opportunity for the learners to be actively engaged in the practical and all other lesson activities. During the lesson presentations learners were provided with worksheets to answer questions and draw concept maps indicating scientific concepts that were emerging from lesson discussions and practical activities.

The observed lessons covered the following sub-topics about light: *reflection, refraction, absorption, and speed of light, formation of image by mirrors and lenses and the applications of the properties of light in everyday life*. Observing more lessons gave me a broader understanding of how learners make sense of many different concepts included in the teaching of the topic light.

Cohen et al. (2007) recommend that observation process allows a researcher an opportunity to gather live data from real situation. It is further indicated that through observation the researcher can look directly at what is taking place in situation instead of relying on second-hand information (ibid).

Although the observation is known to be the appropriate and effective method of collecting data in qualitative research, it can be potentially intrusive, and even if the researcher tries not to interfere with anything, the observation changes the dynamic situation (Bertram & Christiansen, 2015). Furthermore, it was noted that the researcher's presence in the classroom may have caused the teacher and the learners to behave differently (ibid). It means that the researcher needs to focus only on what he/she intends to observe bearing in mind that other things happening in the classroom may be based on history such as jokes as part of the social interactions happening in the classroom .

All the observed lessons were videotaped to create room for stimulated recall interviews with learners while watching the video. The purpose of stimulated recall interview was to seek further clarification on the aspects of the lesson that could not be captured well during observation. During the stimulated recall interviews I asked learners to give reasons on some aspects that were not clearly captured during the lesson observations as well as some responses, actions and behaviours that needed to be clarified in order for me draw up informed conclusions.

The purpose of lesson observation was thus intended to:

- Look into learners' sense making based on their explanations of concepts during the lessons;

- Look into learners’ prior knowledge as how they relate classroom contents to their home and previous experiences about concepts of *light*;
- Look into factors that enable or constrain learners to make sense of the learning topic; and
- Examine how ASEI-PDSI teaching approach helps in correcting errors of understanding to clear the misconceptions or address the learners’ alternative conceptions.

3.6.6 Post-test

As it is appropriate in interpretive paradigm, “the researcher may test the learners before the intervention (pre-test) to ascertain their achievement and then test them again after the intervention (post-test)” (Bertram & Christiansen, 2015, p.95).

After the teaching intervention in which four video-taped lessons were watched, the post-test was administered with all 22 participating learners to evaluate the impact of the ASEI-PDSI teaching approach and to explore whether learners made sense of the topic *light*. All participating learners managed to complete the post-test within the given time and attempted to answer all the questions.

As explained earlier, for validation purposes, the post-test was also adopted from John’s (2014) four tier optics diagnostic instrument and it covered the same content and exactly the same as the pre-test.

The table below summarizes the methods and techniques that were used in this research. It also indicates the research sub-questions addressed by each data gathering method and its purpose.

Table 4: Summary of data gathering methods

STAGES	METHODS	DATA GATHERED	PURPOSE
Stage 1 RQ 1	Questionnaire	Learners’ experiences, views and opinions about the topic <i>light</i> . The data came in the following form: written responses of questionnaire from learners	To get the general learners’ personal and background experiences, views and opinions about the learning of the topic <i>light</i> .
Stage 2	Pre-test	Learners’ prior knowledge, conceptual understanding and sense-making of the topic <i>light</i> . The data comes from in the following form:	To get the learners’ prior knowledge, background experiences and conceptual understanding and sense-making of the topic <i>light</i>

RQ 1& 2		Learners' test written responses that include reasoning of their answers and conclusions drawn on questions.	
Stage 3 RQ 2&3	Stimulated-recall interview	Learners' sense-making, conceptual understanding and prior knowledge of the topic light. The data comes in the following form: Learners' oral responses on the follow-up questions based on their written pre-test answers. Learners' reasoning and further explanations that emerge from their pre-test answers.	To get learners' prior knowledge, sense-making, experiences and identify factors that enable or constrain the learners to make sense of the topic light.
Stage 4 RQ 3	Lesson observations, video-taped lessons and stimulated recall interviews	Learners' comments, discussions, questions, explanations, concept maps or mind maps, actions and behaviors. The data comes in the following forms: Observation schedule, photos, and video and practical activities worksheets.	To seek further clarifications on the aspects of the lesson that could not be captured well during lesson observations. To seek further detailed information to enable me to understand how learners make sense of the topic light and find factors that enable or constrain them to make sense of the topic light.

categories and organise data into each category (ibid). Similarly, Patton (2002) describes inductive analysis as the investigation of data to identify patterns and themes resulting in a creative synthesis.

With regards to deductive reasoning, the researcher is expected to start with a set of categories, which are then used to categorise and organise data into themes based on research questions and theoretical framework informing the study (Bertram & Christiansen, 2015). In this study, I deductively used the following themes: prior knowledge, sense-making, misconceptions, conceptual understanding, conception of the topic light, social and cognitive constructivism. These themes were used to answer all my three research sub-questions (see Section 1.5).

All the data gathered through questionnaires, pre- and post-test, observations and stimulated recall interviews were analysed with the coding system whereby all similar data were coded with the same colour so that I was able to group them as one theme (see Chapter 4). The coding system is defined by Cohen et al. (2011) as the translation of question responses and respondent information to specific categories for the purpose of analysis. I used direct quotations from the participants so that their ideas and *voices* come through in the study. In addition, I was able to generate analytical themes which, as Bassey (1999) says, are based on the raw data, but speak directly to the research questions. The emerging themes from data analysis are interpreted and discussed in Chapters 4 and 5 of this study.

3.8 Validation and trustworthiness

Validity, as defined by Creswell (2012), is the development of sound evidence to demonstrate that the analysis about concepts is assumed to match its use. To ensure validity and trustworthiness in my study I used various methods of gathering data, namely, questionnaires, pre-test and post-test, observation and stimulated recall interviews. The administering of multiple methods of data collection is preferred and regarded helpful in data triangulation and building on each type of data gathering while simultaneously compensating for any potential weaknesses in any single approach (Patton, 2002). In my study, triangulation of data was used for the data to complement each other and look for consistencies, patterns and discontinuities in the data gathering process. Triangulation is defined by Cohen, et al. (2011) as the use of more than one different methods of data collection.

Triangulation techniques in the social sciences attempt to map out, or explain more detail, the richness and complexity of human behaviour by studying it from more than one standpoint. Triangulation is a powerful way of demonstrating concurrent validity, particularly in qualitative research (Cohen et al., 2010, p.141).

Before the learners completed the questionnaires, pre- and post-test, these data collection instruments were validated, checked, edited and moderated by fellow Masters of Science Education students,

after which I worked on their comments, suggestions and advice. This was done to ensure validity of data collected through those instruments.

Watching the video-taped lessons with learners and conducting the stimulated recall interview with them, gave me an opportunity to understand what actually transpired during the lessons more in detail. In addition, the transcription of both the audio and videotaped materials afforded me opportunity to reflect on what actually happened and thus I was able to describe the situation.

3.9 Ethical considerations

Firstly, I obtained a written consent from Ohangwena Regional council via the Office of the Director of Education to grant me the permission to conduct the research study in the region (See Appendix A). I also obtained written consent from the principal of the selected school and the Grade 11 Physical Science teacher who delivered all the four observed and video-taped lessons (see Appendix A & B). Permission from parents of learners (see Appendix D) in the selected Grade 11 class groups were also granted and allowed me to involve learners in my study as research participants. All participants confirmed their agreement by endorsing the letter of agreement which is filed for future reference. Additionally, the learners who participated in this study also gave consent to be part of this study.

Cohen et al. (2011) define informed consent as a process of granted permission from instructions amenities for research. The purpose and the nature of the research study were made clear to all participants before they made the decision to take part. It clearly indicated that during interview and lesson observations, video and audio recorder would be used and were assured that all the collected data would be used for the intended purpose of the study only. Throughout the research report pseudonyms have been used to protect the school and participants' identities.

3.10 Limitations of study

The results of this study are limited to Z Secondary School (pseudonym) in the Ohangwena region and therefore they cannot be generalised. Findings from one Grade 11 class only might not reflect a reality of how all learners make sense of the topic light in Namibian schools. However, some insights on how learners make sense of the topic light may be obtained from this case study.

Sadly, at the beginning of the data collection process, the Physical Science teacher who was supposed to deliver all the ASEI teaching approaches passed away in a car accident. Such a situation might have affected these learners psychologically. I had to seek the consent of another experienced Physical Science teacher (Mr B) at the same school who might not have the same expertise as the one

who deceased. So, it could be surmised that the changing of teacher participants might have affected the quality of the expected lessons that I observed.

3.11 Concluding remarks

In this chapter I described the research design I used in this study. I further discussed the data gathering techniques used to generate data in order to answer my research questions. Questionnaires, observations and stimulated recall interviews were used as the main techniques for the generating data in this study. I also explained the method of data analysis and how data were interpreted to draw conclusions from the findings and triangulation of data was discussed as appropriate for my study to ensure high degree of data validation. Finally, I reported on the issue of ethical consideration and limitation of the study.

In the next chapter I present, analyse and discuss the data generated in this study.

CHAPTER FOUR:

DATA PRESENTATION, ANALYSIS AND DISCUSSION (PHASE ONE)

4.1 Introduction

In this chapter, I present, analyse and discuss quantitative and qualitative data generated through the pre-test, post-test, learners' explanatory answers and stimulated recall interviews. The identification of sub-themes, and subsequently themes, was based on constructivist theory which is my theoretical framework in this study.

The data generated provided answers to the following research sub-questions by using various data gathering techniques:

- What are the Grade 11 Physical Science learners' conceptions and experiences of the topic light before and after an ASEI-PDSI intervention was implemented? How does an ASEI-PDSI teaching intervention influence Grade 11 Physical Science learners' conceptual understandings of the topic light?
- What factors enable or constrain Grade 11 Physical Science learners to make sense of the topic light?

I start by presenting the quantitative data first.

4.2 Quantitative results

The data obtained from the pre-test and post-test were quantitatively analysed, presented and discussed to answer my sub-research questions 1 and 2 so that I could explore the level of learners' experiences and conceptual understanding of the topic *light*. In addition, I used this quantitative data to measure, assess and evaluate the impact of the ASEI teaching intervention on learners' sense making of the topic light by comparing the pre-test and post-test results.

4.2.1 Results from the pre-test

The main purpose of the pre-test in this study was to assess or elicit learners' prior knowledge of the topic *light*. This was intended to determine their level of content knowledge with regard to sense making of the topic *light* before the ASEI teaching intervention was implemented.

Figure 1 below shows the results of the pre-test that was written by 22 Grade 11 Physical Science learners at Z secondary school (Pseudonym).

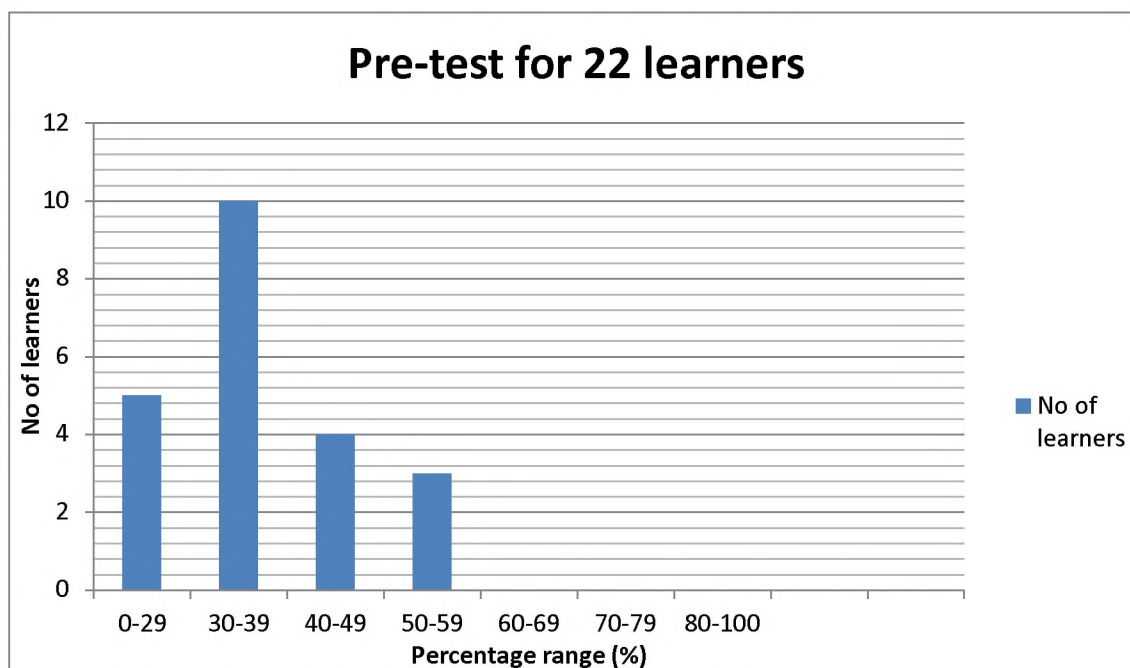


Figure 1: Pre-test results

The distribution of marks reflected in Figure 1 revealed that only three learners managed to score marks in the range of 50% to 59%. According to NSSCO level Physical Science (2010) promotional requirements, a range of 50% to 59% represents a D symbol which is equivalent to 4 points. The other 19 learners scored marks below 50% which shows that their prior knowledge with regard to the content of topic *light* was quite low.

The detailed analysis of the scores for all questions in the pre-test from all 22 learners is reflected in Table 3 below (See pre-test question paper on Appendix K).

Table 5: Detailed scores for pre-test

Question number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Marks per question	2	2	4	2	2	2	2	2	2	2	2	2	2	2	2	32
Learners																
L1	1	1	0	0	0	0	0	0	0	0	0	0	0	2	1	5

L2	1	1	0	2	2	0	1	0	0	0	0	2	0	0	0	9
L3	2	0	2	0	1	2	2	0	2	2	0	2	1	1	1	18
L4	1	0	2	1	0	0	1	0	0	1	1	2	0	1	0	10
L5	2	0	3	0	0	0	0	0	1	1	1	2	0	0	2	12
L6	2	0	1	1	0	0	0	0	2	1	0	2	0	1	2	12
L7	1	1	2	1	0	0	0	0	0	1	1	1	1	1	0	10
L8	1	2	3	0	0	2	2	0	1	2	0	0	1	0	0	14
L9	0	1	2	1	1	0	0	0	0	0	1	2	0	1	1	10
L10	2	1	4	0	1	0	0	0	1	1	0	2	0	0	1	13
L11	1	0	3	2	2	1	0	0	0	0	0	2	2	2	2	17
L12	1	1	2	0	1	0	0	0	0	0	0	2	0	0	0	7
L13	1	0	2	2	0	0	1	0	1	1	1	2	1	0	1	13
L14	2	0	2	0	0	0	0	0	1	2	0	2	0	1	1	11
L15	2	2	0	2	1	0	1	0	2	0	0	2	1	1	2	16
L16	2	1	1	0	1	0	0	0	0	0	1	0	0	1	0	7
L17	2	0	3	0	0	0	2	0	0	0	1	2	0	0	0	10
L18	0	1	2	0	0	0	0	0	1	0	0	0	0	0	0	4
L19	2	2	3	2	1	1	1	0	0	0	1	1	1	0	0	15
L20	1	0	2	0	1	0	0	1	2	2	0	1	0	1	0	11
L21	1	0	2	2	0	2	2	0	0	0	1	1	0	0	0	11
L22	1	0	2	1	0	0	0	0	0	2	0	2	0	1	2	11
Average	1.3	0.6	1.8	0.8	0.5	0.4	0.6	0	0.6	0.7	0.4	1.5	0.4	0.6	0.7	11.2

Table 5 above indicates that only two questions were well answered by the majority of learners. Most questions were poorly answered, while others were not attempted by some learners.

In the context of this study, well-answered questions were indicated by the average mark which was equal or greater than half the total marks. Table 5 further indicates that questions 1 and 12 were well-answered. In these two questions, learners managed to score 50% and above. In question 1, learners were expected to choose the coloured paper which can be easily seen in the darkness and provide reasons for their choices, while in question 12 learners were expected to choose the value of the angle of reflection when the angle of incidence (30°) was provided and give reasons for their answers. The following are samples of learners' responses in questions 1 and 12 (Appendix G).

Question 1:

L5	<i>B) I am sure because the white colour is good in reflecting the light.</i>
L6	<i>B) Because white colour reflect light.</i>
L10	<i>B) White because is a good reflector it can reflect any source of light come o it while black is good absorber light will get in but not get out.</i>

Question 12:

L1	<i>B) The angle of reflection is just equal to the angle of incident.</i>
L4	<i>B) Because the angle of incidence is equal to the angle of reflection.</i>
L6	<i>B) Because the angle of incidence is equal to the angle of reflection.</i>

Although the overall performance of learners was poor, the result of pre-test revealed that most learners had content knowledge with regard to the identification of colours that reflect more light than others as well as the law of reflection. Most learners' explanations of their chosen answers indicated that their prior knowledge enabled them to make sense in answering these two questions.

In question 8, only one learner managed to score 50% while 21 learners scored 0% in this specific question. The average mark score in this question was therefore 0%.

In question 8, learners were expected to choose the correct option as to what happens to the height of the image of the pencil in the mirror when the pencil is moved a little further from the mirror while the lamp stays fixed as indicated by Figure 2 below.

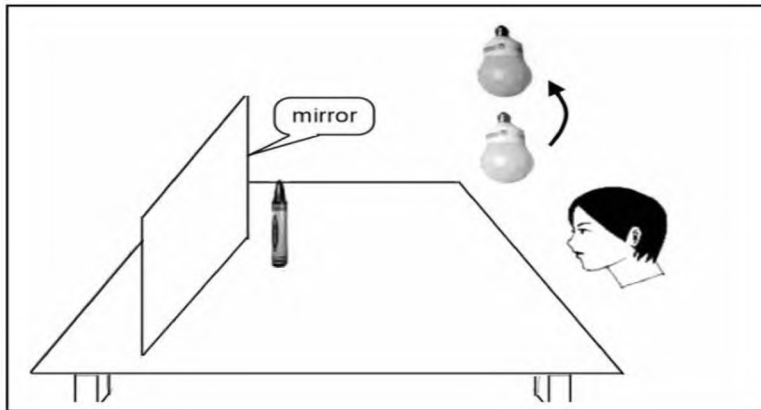


Figure 2: Picture from pre-test in questions 7 and 8

The following are the samples of learners' responses in question 8 (Appendix G).

Question 8:

L1	<i>B) The more you are moving it back further from the mirror; the image will become shorter because the distance is decrease.</i>
L6	<i>B) The closer the object to the mirror the larger the image.</i>
L17	<i>B) Because the shorter the light, the longer the image. The higher the light the shorter the image.</i>

Based on learners' responses in question 8, there is an indication that learners do not understand how changing the distance of the object in front of the plane mirror affects the height of its image in the mirror. They chose the wrong answers and their explanations indicated that they could not make sense of the options when answering this question.

Table 5 indicates that only three learners (L3, L11 and L15) managed to score above 50% in the pre-test while the other 20 learners all scored below 50%. The total average mark scores in the pre-test were 11.2 out of 32 marks allocated for the whole test. This represents a 35% learners' pass rate in the pre-test.

The learners' responses from the pre-test indicated that some learners had spelled scientific concepts wrongly resulting in the whole sentence not to make sense. Below are the samples of some learners' responses from pre-test with incorrect spelling of science concepts in questions 2, 9, 11, 12, 13 and 15 (Appendix G):

Question 2:

L6: *When the light reflect back to the mirror it reflect back.*

L5: *The flashlight should be aimed at his chin will reflect light into the mirror.*

Question 9:

L1: *It will refract from the mirror, the location of the image refract from the mirror.*

Question 11:

L21: *The mirror can send back the light as it heats it it.*

Question 12:

L7: *because the angles of reflection*

Question 13:

L6: *the angle of refraction*

Question 15:

L1: *light can only be faster when travelling in an empty space.*

It is based on this evidence that most learners who wrote the pre-test could not make sense when answering most questions related to topic *light*. English as a medium of instruction inhibited learners' sense making in the pre-test. Apart from the use of English, however, the results from the pre-test indicated that some learners had misconceptions as reflected by their responses to some questions. Below are the samples of some learners' responses with misconceptions from question 6, 7, 8, and 9.

Question 6:

L4: *If you move the lamp up, then the pencil will move down.*

L9: *As the lamp is raised the image will move down.*

Question7:

L1: *The image will become longer because the more you are raising highly the lamp the more the image is becoming longer.*

L12: *Because the lamp is raised a little higher, so the image will become shorter, just because the observer can see it shorter as the lamp is up higher little.*

L16: *Because the lamp is raised higher up the image will become shorter because there is a short distance from the mirror and a source of light.*

Question 8:

L1: *The more you are moving it back further from the mirror, the image will become shorter because the distance is decrease.*

L11: *Because the closer the pencil to the mirror. The image becomes shorter. As you move further the pencil away more area of the pencil will be seen in the image.*

L17: *Because the shorter the light, the longer the image. The higher the light the shorter the image.*

Question 9:

L21: *The size of the pencil in the mirror will be seen smaller as the observer moves away from the lamp.*

The learners' results from the pre-test informed me to conduct the ASEI teaching approach in exploring how the Grade 11 Physical Science learners make sense of the topic *light*.

4.2.2 Results from post-test

At the end of the ASEI teaching intervention, a post-test was administered to 22 learners to assess their sense-making of the topic *light* and to evaluate the impact of this intervention in influencing learners' sense-making. Figure 3 and Table 6 below show the learners' average percentage scores from the post-test.

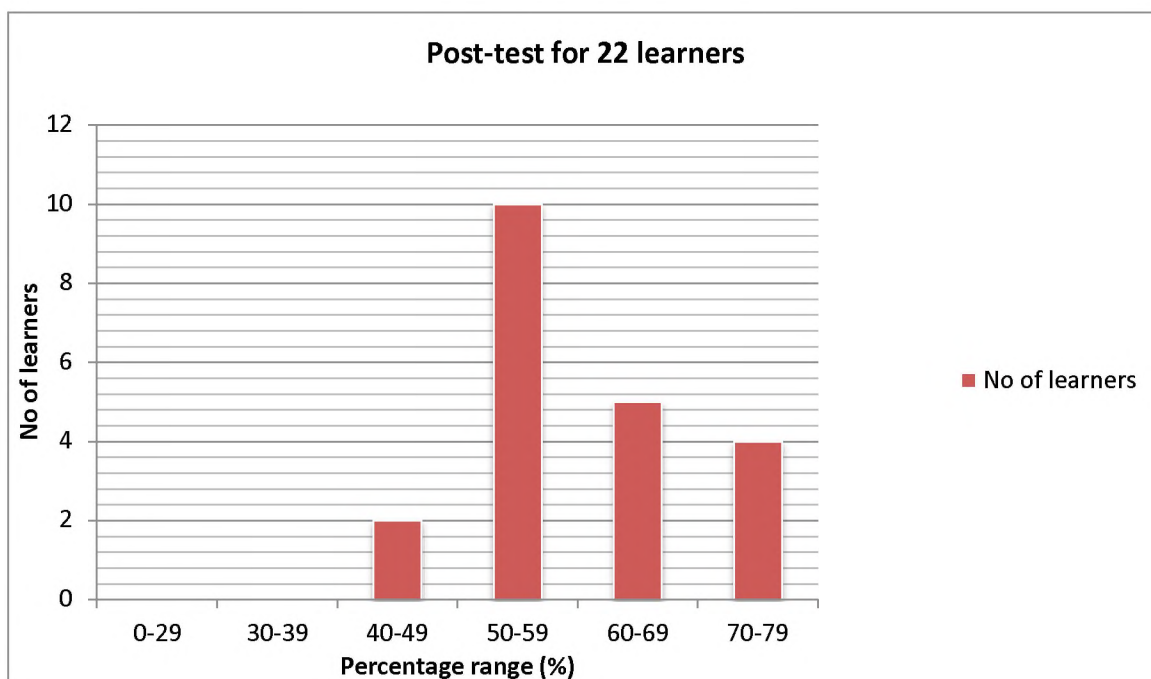


Figure 3: Results from post-test

The distribution of marks reflected in Figure 3 presents the percentage range of marks scored by learners in the post-test: two learners scored marks within a range of 40% to 49%, 10 learners scored marks within a range of 50% to 59%, four learners scored marks within a range of 70% to 79%, while one learner managed to score marks a range of 80% to 100%. Unlike in the pre-test results, none of the learners obtained marks below 40% in the post-test.

According to NSSCO level Physical Science's (2010) promotional requirements, a range of 60% to 69% represents a C symbol which is equivalent to 5 points; a range of 70% to 79% represents a B symbol which is equivalent to 6 points, while the range of 80% to 100% represents an A symbol which is equivalent to 7 points. Figure 3 shows that 91% of the 22 learners managed to score 50% and above in the post-test while only 9% of them obtained marks below 50%. This is an indication that most learners were able to make sense of concept of *light* in answering most questions in the post-test.

The detailed analysis of the scores for all questions in the post-test from all 22 learners is reflected in the Table 6 below.

Table 6: Detailed scores for post-test

Question number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Marks per question	2	2	4	2	2	2	2	2	2	2	2	2	2	2	2	32
Learners																
L1	2	1	2	0	0	2	2	2	2	1	2	2	0	0	2	20
L2	2	1	2	0	1	1	1	1	0	1	2	2	2	0	2	18
L3	1	2	3	0	2	2	2	0	2	2	1	2	2	0	2	23
L4	2	2	4	0	0	0	1	1	1	2	2	2	1	1	2	21
L5	2	1	4	0	2	2	0	0	2	2	2	2	0	0	2	21
L6	2	2	4	0	0	0	0	1	1	0	2	2	2	0	2	18
L7	2	1	4	2	1	0	0	0	0	2	2	2	1	0	2	19
L8	2	2	4	0	1	2	2	0	2	1	2	2	2	0	2	24
L9	2	2	3	2	1	0	0	0	0	1	1	2	2	1	2	19
L10	2	2	4	0	1	2	2	2	2	2	2	2	1	2	2	28
L11	2	2	4	2	2	2	0	0	2	0	0	2	1	1	2	22
L12	1	2	2	0	1	0	0	0	0	1	1	1	1	1	2	13
L13	1	2	4	0	0	0	0	1	2	1	1	2	2	0	1	17
L14	1	0	4	2	0	0	0	0	2	2	2	2	0	1	0	16
L15	1	1	4	2	1	2	2	0	2	0	0	2	2	0	2	21
L16	2	1	4	0	1	0	0	0	0	0	0	2	1	0	2	13
L17	2	1	3	2	1	2	0	1	0	0	0	2	0	1	2	17
L18	2	2	4	2	1	2	2	0	2	0	2	1	1	1	1	23

L19	1	0	4	2	1	2	0	0	0	1	0	2	2	0	2	17
L20	2	2	4	0	2	0	0	2	2	2	2	2	2	1	2	25
L21	2	1	3	2	1	2	1	1	1	0	0	2	1	0	2	19
L22	2	0	4	2	1	1	2	1	2	0	0	2	0	0	2	19
Average	1.7	1.4	3.5	0.9	0.6	1	0.8	0.6	1.2	1	1.2	1.9	1	0.5	1.8	19.7

As indicated in Table 6 above, most questions were well-answered by the majority of learners in the post-test. The total average marks scored by 22 learners was 19.7 out of 32 marks, representing a 62% overall learners' pass rate in the post-test.

Learners obtained average mark scores equal to 50% and greater than 50% in questions 1, 2, 3, 6, 9, 10, 11, 12, 13 and 15. Although these questions were well-answered, the highest scores above 80% were recorded in the following questions: question 12 (95%), question 15 (90%), question 3 (87%) and question 1 (85%). In questions 1, 3, 12 and 15, learners were expected to choose the correct answers and then provide reasons for their choices. These questions were related to the identification of coloured papers that reflect more light, reflections by plane mirror, images formed in the plane mirror, the law of reflection of light, refraction of light and speed of light in different mediums (Appendix H). Based on the learners' responses from these questions, there was an indication that most learners were making sense when answering these questions.

The following are the samples of 22 learners' responses from question 15 about the speed of light (Appendix H).

Question 15:

L1	<i>B) In a vacuum there are no air particles which broke the light.</i>
L2	<i>B) Because in a vaccum there is nothing to lock the air particles, is an empty space.</i>
L3	<i>B) In the vacuum there no particles, so there will be no any brokage of light rays.</i>
L 4	<i>B) Because vacuum is the empty space without particles and the light can travel in fast.</i>
L5	<i>B) Because vacuum does not have any particles and its less denser than the glass.</i>

L6	<i>C) I have no valid reason why.</i>
L8	<i>A) Vaccum is a space where there is no any gases but light travel in place where there is oxygen and carbon dioxide.</i>
L9	<i>A) Because there are no particles.</i>
L10	<i>B) (Certain). Light are faster in the vaccum because vacuum is light conduct.</i>
L11	<i>A) (Almost certain). Because in the vacuum there are not particles inside to carry out light there.</i>
L12	<i>B) Light will travel faster in the vacuum because there are no particles in the vacuum and in the glass there is.</i>
L13	<i>A) Because light cannot pass through a vaccum.</i>
L14	<i>B) Light travel only in a vacuum like in air.</i>
L15	<i>B) It travels faster because the vacuum is an empty space with no particles that can decrease the speed of light, so light faster in a vacuum.</i>
L16	<i>A) There is no particle to carry vibration.</i>
L17	<i>B) Because light can travel in any medium.</i>
L18	<i>B) Because in a vacuum there no air particles.</i>
L19	<i>B) Because light travel in a vaccum.</i>
L20	<i>B) Light travel faster in the vacuum only the sound can not travel in the vaccum.</i>
L21	<i>B) Because light travels with a higher speed since there are no other things.</i>
L22	<i>B) Vaccuum consist of gas particles that are loosely arranged.</i>

Although, 17 learners managed to choose option B (light travels faster in the vacuum) which is the correct answer, a few learners could not provide the correct explanation of this choice.

Table 6 shows that learner 10 (L10), managed to score the highest total marks of 28 out of 32 (87.5%) while learner 12 (L12) and Learner 16 (L16) scored the lowest marks of 13 out of 32 (40.6%) pass rate. Table 6 also indicates that the following questions were poorly answered in the post-test: 4, 5,

7, 8 and 14, for which learners managed to score average marks below 50%. In these questions learners were expected to choose the correct answers in relation to the following: how the change in position of the object in front of the plane mirror affect its image in the mirror; how changing of the location of source of light affects the height and size of image of the object in front of the plane mirror; how the changing of the distance of the object in front of the mirror affects the height of its image in the plane mirror; and how a concave lens can be used to correct short-sightedness eye defect (Appendix H). Learners' responses from these questions showed that they were struggling to make sense when answering these questions. Table 8 indicates that the lowest average marks scores of 0.5 out of 2, which represents 25% pass rate was recorded in question 14. It is evident that most learners do not know how the changing in position of the object in front of the plane mirror affects its image in the mirror.

The post-test results showed that learners had improved compared to the pre-test results. In the following section I present and discuss the specific individual change in scores for the two tests.

4.2.3 Comparison of pre-test and post-test results

Table 7 represents the comparison of pre-test and post-test results of 22 learners in order to assess the effect of the ASEI teaching intervention in learners' sense making of the topic *light*. The degree of variation was used to measure the impact of ASEI teaching interventions in influencing the learners' sense making of the topic *light*. Table 7 and Figure 4: below show the degree of variation of individual learners' performance in pre-test and post-test.

Table 7: Difference in scores between pre-test and post test

Learner	Pre-test score marks	Post-test score marks	Variation
L1	16%	63%	47%
L2	28%	56%	28%
L3	56%	75%	19%
L4	31%	66%	34%
L5	38%	66%	28%
L6	38%	56%	19%

L7	31%	59%	28%
L8	44%	75%	31%
L9	31%	59%	28%
L10	41%	88%	47%
L11	53%	69%	16%
L12	22%	41%	19%
L13	41%	53%	13%
L14	34%	50%	16%
L15	50%	66%	16%
L16	22%	41%	19%
L17	31%	53%	22%
L18	13%	72%	59%
L19	47%	53%	6%
L20	34%	78%	44%
L21	34%	59%	25%
L22	34%	59%	25%
Average	35	62	27

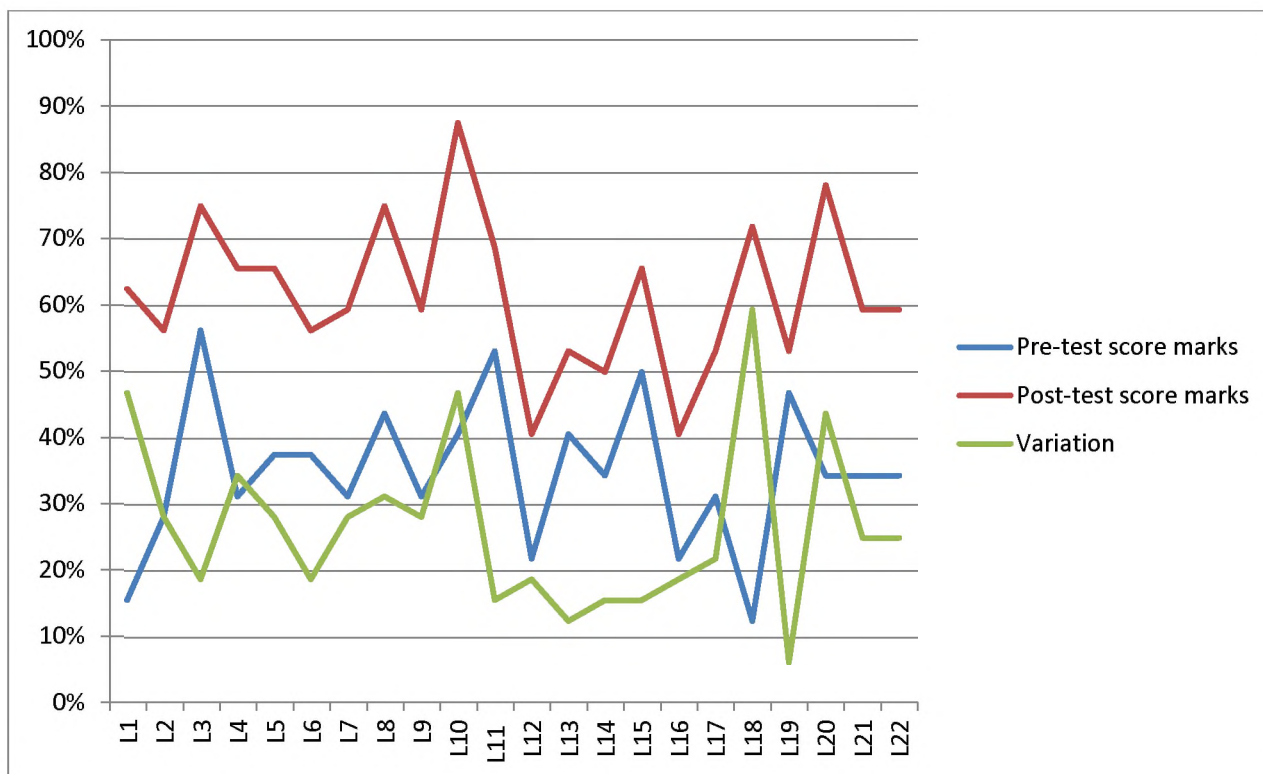


Figure 4: Difference in scores between pre-test and post-test

You need a caption/heading for this graph. Also, you need to label the x-axis as well as the y-axis.

The quantitative data from both tests was used to demonstrate the degree to which individual learners made sense of topic *light* through the ASEI teaching approach. Table 7 and Figure 4 indicate that after the teaching intervention, learners' overall performances improved by 27%. Learners' performance in the pre-test was 35% and it improved to 62% in the post-test. The variations in Table 7 and Figure 4 indicate that all individual learners' results showed improvement in the post-test compared to the pre-test. This is an indication that the ASEI teaching approach positively influenced the learners' performances in the post-test. It could be deduced that in the post-test many learners were able to make sense when answering most questions compared to the pre-test. Furthermore, Table 7 indicates that learner 18 (L18) shows the highest improvement by increasing the result from 13% in the pre-test to 72% in the post-test, showing the difference of 59%. Learner 19 (L19) produced the lowest variation from 47% to 53%, which is an increase by 6% in the post-test.

4.3 Discussion of quantitative results

The results are discussed in relation to how they answered research questions. The quantitative results in Sections 4.2.1, 4.2.2 and 4.2.3 are discussed as findings to answer research sub-questions 1, 2, and 3 respectively.

4.3.1 The Grade 11 Physical Science learners' conceptions and experiences of the topic *light*

Based on the pre-test, three learners managed to obtain 50% and above, while the other 19 learners obtained marks below 50% (Figure 1 and Table 5). In responding to questions in the pre-test, learners used their prior knowledge to choose the correct answers and provide reasons for their choices. According to Roschelle (1995), prior knowledge refers to all the experiences, skills and knowledge about the subject matter learners bring to school. As a result, 13.6% of the learners who wrote the pre-test were able to apply their prior in answering questions and make sense of their explanations. Although learners obtained low marks in the pre-test, they managed to use their prior knowledge to answer question 12 (75%) correctly. This is supported by Cook (2006), who states that learners make meaning of the classroom science based on what they already know. In this context, learners used their prior knowledge from Grades 7 and 10 where this topic was previously offered to them.

Figure 1 and Table 5 indicate that 86.4% of the learners obtained marks below 50% in the pre-test. Their responses indicated that some learners' prior-knowledge is not related to the school science with regard to the topic *light*. According to Oloruntegbe and Ikpe (2011), many learners find it difficult to create a clear linkage between classroom science concepts and science concepts embedded in their everyday experiences. It is based on this that I found many learners chose wrong answers in the pre-test, especially in questions 6 and 8, and hence they obtained average percentages of 1.3% and 0% respectively. It is evident that, before the ASEI teaching intervention, learners had little knowledge about light as it is reflected by their results from pre-test in Figure 1 and Table 5.

4.3.2 The Grade 11 Physical Science learners' conceptual understandings of the topic *light*

The post-test results show a change in learners' conceptual understanding of the topic *light* compared to the pre-test.

After the ASEI teaching intervention, learners' conceptual understanding related to the topic *light* improved significantly. This is reflected in Table 7, as post-test results show an increase by 27% shifted from 35% in the pre-test to 62% in the post-test. According to Rotich and Mutisya (2013), ASEI-PDSI is a possible development in science as it has given learners opportunities to explore and satisfy their curiosity. So, it could be argued that the positive variation (+27%) between the pre-test and post-test results happened as a result of ASEI intervention.

In the post-test, most learners chose the correct answers in most questions and their explanations of their answers indicated sense-making of the topic *light* (Appendix H). These findings corroborate with Sutchcliffe and Weick's (2005) findings that learners' actions and interpretation of the learning content determine how they make sense of science concepts. Similarly, in the context of this study,

the increased result from the post-test served as an evidence of learners' action and correct interpretation of learning content of the topic *light*.

4.3.3 Factors that constrain Grade 11 Physical Science learners to make sense of the topic *light*

Based on the learners' results from the pre-test, there is an indication that the learners' prior knowledge and the language of learning and teaching (LoLT) are some of the factors that constrained their sense making in the learning of topic *light*.

In the context of this study, the LoLT is English, which is the second language of all learners of school Z. There were inaccurate spellings of scientific words in some learners' responses from the pre-test (Appendix G). Those spellings were influenced by learners' English proficiency as they did not recognise that their spelling of concepts made the whole sentences to be senseless in that they could not be understood scientifically. These findings are supported by Noordin and Yong (2009), who posit that most learners who are English second language speakers do not have necessary tools to make sense of advanced science concepts. It is due to this reason that some learners used Basic Interpersonal Communication Skills (BICS) instead of Cognitive Academic Language Proficiency (CALP) when explaining their answers in the pre-test. These two kinds of languages were distinguished by Cummins (1986).

Apart from English language, the results from the pre-test indicated that learners had several misconceptions in relation to topic *light*, particularly when answering questions about how changes in the position, location, and height of a light source, objects can affect the appearance of the image in the plane mirror. These findings are similar to that of John (2014) in her study conducted in South Africa, in which she found that learners believe that the position/location of an image in the mirror changes when the position of light source is changed. In this study, for instance, learners indicated that when the source of light is moved upward the reflection from light moves downward. Another similar findings on learners' misconceptions by John (2014), is that some learners believe that the image size in the plane mirror decreases when the viewer or observer moves away from the mirror and increases when the viewer moves closer to the mirror.

These misconceptions are influenced by learners' prior knowledge. As indicated by Roschelle (1995), prior knowledge can produce mistakes. Furthermore, Stears et al. (2003) had similar findings that the science in the community differs from the school science, meaning that scientific concepts used in schools are abstract, idealised and focused more on the textbook world. In this study some learners

indicated that reflected light from the mirror carries the image for the person to see it, while others referred to an image being the same as shadow. It was due to this evidence that it can be understood that sense-making can be inhibited by some of these factors.

4.4 Qualitative Results

Data from questionnaires, explanatory answers from pre-test and post-test and stimulated recall interviews were analysed purposively with selected learners. The collated data and interview transcripts were analysed and a range of categories of data that emerged from the transcripts were further sorted together, based on their similarities and differences. The sub-research questions in the study led to classification of the sub-themes and themes which served to show how learners made sense of the topic *light* through ASEI teaching interventions.

Table 8: Creating Preliminary sub-themes from codes

Marked text	Description	Sub-themes	Sub-questions
L1,L2, L5, L6, L8, L9, L10, L11, L12, L14, L15, L22	Definition of scientific concepts, Giving out examples to support the defined concepts	Sense-making	2
L1, L2, L3, L4, L6, L11, L12, L13, L15, L16, L17, L18, L19, L22	Application of light in everyday life, uses of light, Natural phenomenon such as lunar and solar eclipse, formation of rainbow, shadow and mirages	Prior-knowledge	2 & 3
L1, L2, L4, L6, L8, L10, L11, L12, L14, L15, L16, L17, 18, L19, L22	Necessary to learn about light, importance of the topic light, uses of light, enjoying the lessons of light	Usefulness of topic light	1
L1, L2, L6, L7, L10, L20, L14, L18, L22, L4, L8	Knowledge of properties of light, and its uses, knowledge of how light travel and its speed in different mediums	Content knowledge	2
L1 to L22	Group works, Group discussion and presentations	Social interaction	3

Thereafter, I combined preliminary sub-themes to form themes. Three themes emerged to explore how Grade 11 physical science learners make sense of the topic *light*. These are:

- Perception of the topic light;
- Link science concepts to everyday life; and
- Construction of knowledge.

The three themes are described with supporting theory/literature as shown in Table 8. Phrases that were direct quotes from the interview transcripts were used in the narrative to provide a sense of the learners' own words and to allow interpretations in relation to the research sub-questions.

Table 9: Themes and supporting theory/literature

Themes	Research sub-questions	Theory/literature
Theme 1: Perception of the topic light		
Necessary to learn about light, importance of the topic light, enjoying the lessons	1	MoE (2010), Eaton et al. (1986), John (2014), Alev and Karal (2013)
Theme 2: Link science concepts to everyday life		
Application of light in everyday life, uses of light, Natural phenomenon such as lunar and solar eclipse, formation of rainbow, shadow and mirages	2 & 3	Roschelle (1995), Kasanda et al. (2005), Mukwambo (2012), Stears et al. (2006), Meyer (2012), Ryder (2001), Srikantain (2005), Cook et al. (2001), Meyer (2006), Nylor and Keogh (2002), Oloruntegbe and Ikepe (2011), Okere (1986), Moll (2002),. Kamini (2001)
Theme 3: Construction of knowledge		

Definition of scientific concepts, Giving out examples to support the defined concepts, Knowledge of properties of light, and its uses, knowledge of how light travel and its speed in different mediums	3	Vygotsky (1978), Bruner (1957), Stears et al. (2003), Mukwambo (2012), Lamke (1990), Kamini (2001), Noordin and Yong (2009), Millar (2004), Hodson (1990), Parkinson (2002), Roberts (2004), Millar (2010), Hatting and Rogan (2007), Maselwa and Ngcoza (2003), Woodyley (2009), Ramsden (1994), Gathumbi et al. (2013), Changeiywo et al. (2013), Rotich and Mutisya (2013), Gray (2004), Atherson (2009), Wertsch (1985),
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4.5 Grade 11 Physical Science learners' perceptions of the topic *light*

The qualitative results are discussed with the view to answering all three research sub-questions 1, 2 and 3 of this study. From learners' questionnaires, explanatory answers from the pre-test and post-test and stimulated-recall interview transcripts, three themes were identified to explore how Grade 11 Physical Science learners make sense of the topic *light* (see Table 9). Words and phrases that were direct quotes from the transcripts are included in the narrative of the learners' own voices in order to understand the interpretations relevant to the research questions.

4.5.1 Perceptions of the topic *light*

Learners' responses from the questionnaire indicated that most learners perceive light as a very important topic. They indicated that it is necessary for them to learn about light in school as it plays important roles in their daily life. The following are some samples of learners' responses from question 1 of the questionnaire (Appendix F).

Question 1:

L4: *"Yes, because things that we learn in light are those that we use in everyday life".*

L5: *"Yes its necessary because is only in school you can learn what are the important of light." "If there was no light we cannot see well during night time".*

L18: *"I think it is necessary to learn about light because everywhere you go there is light e.g.; sunlight, lamp light and so on".*

L22: *"I think its more important to learn about light because without light we cannot able to see objects and carry out work but if there is light everything can be possible and easy to study with".*

It is evident that learners recognise the importance of light in everyday life and are willing to learn more about it in school science. That learners know that light is important based on their everyday prior knowledge, as they indicated the necessities of learning about the topic *light* in relation to their daily life experiences. This is perceived by Mukwambo (2012) as being important that consideration of prior everyday knowledge and experiences would engage learners in a new learning situation.

Furthermore, learners' responses from question 2 in the questionnaire revealed that most of them feel good, comfortable, excited and happy whenever attending lesson on the topic *light*. The following are the samples of learners' responses from question 2 in the questionnaire (Appendix F):

Question 2:

L1: *"I feel proud because I want to know how to use light and how to control it"*.

L6: *"During this topic of light I feel very happy because I learned more about light and its importance to different things especially to living things"*.

L8: *"I feel good because our teacher like to teach us how light can work and how light can travel in a vaccum"*.

L16: *"I feel interesting because my dream is to become an optician, so I find the lessons interesting because I'm gaining knowledge about future career"*.

L17: *"I feel excited and impressed because I do learn things that I mostly know already"*.

The learners' interests in the topic *light* are mostly influenced by their prior everyday knowledge. Most of them indicated that in this topic they learnt about things that are familiar already and one of them of them (L16) was interested in becoming an optician. Hence, she found the lessons interesting for her future career. It is due to those factors that Meyer (2004), states that teachers should appreciate what learners already know and develop learning experiences that provide them with opportunities to keep their knowledge to accommodate new skills and scientific knowledge for better understanding. In the context of this study, learners' prior knowledge was integrated in the ASEI teaching intervention to build on the new scientific knowledge as discussed in Chapter 5. This study found out that learners had a positive attitude toward the learning of the topic *light*.

4.5.2 Link science concepts to everyday life

The learners' responses from the questionnaire indicated that they were able to link the science concepts to natural phenomenon. This was an indication that learners used their prior knowledge to

link classroom science to natural phenomenon. This is evidence that learners' responses had some elements of sense-making of the topic *light*. The following are some samples of learners' responses from the questionnaire (Appendix F):

Question 1:

L13: *"All children will really like this topic because they will learn how light is reflected, how a rain bow is formed"*.

L22: *"Because one is supposed to know how light works learning about light gives us the opportunity to know how and why shadows are formed, because it is caused by light"*.

Question 2:

L12: *"helps me to know about eclipses, the two types or it, the sun and the moon eclipse"*.

Question 3:

L3: *"The uses of light such as to make someone to see well during night. Formation of shadows"*.

L12: *"Eclipse is the one + enjoy most because it make me know about the two types of it e.g sun eclipse which happen when the moon is between the sun and the earth and also the moon (lunar) eclipse this the only topic"*.

Question 5:

L13: *"Lightning is seen 1st and the thunder is heard after-Whaching a person far from me chopping wood and I can see the action he is doing and hear the sound late"*.

Since this questionnaire was administered before the ASEI teaching approach, there is evidence from the learners' responses that they were making sense of their answers based on their prior knowledge. A similar argument is supported by Srikantaih (2005), who defines prior knowledge as experiential knowledge that learners bring to school that influences how they make sense of the learning contents. Concurring, Kasanda et al. (2005) emphasize the need to use learners' existing knowledge/skills and to include learners' everyday experiences in order to introduce a topic.

4.5.3 Construction of knowledge

The learners' responses from the pre-test, post-test and stimulated recall interview indicated that some learners had content knowledge of the topic *light*. This is an indication that some learners were able

to construct knowledge before the intervention while others were influenced by the intervention. Hence, they were able to construct knowledge during and after the ASEI intervention. The following are some samples of learners' responses in question 2 from the post-test showing some evidence that sense-making and knowledge construction took place (see Question 2 in Appendix H):

L3: *"Because the light from the source hit on the Zebra and it is reflected to the surface of the water to form an image in the water just like a mirror".*

L8: *"As light travel from the source they hit on the object (zebra) and reflected in water and reflected back on you, to see the image formed in water".*

L20: *"Because water surface acted as a mirror, simply because when light is supplied by the light source which can be a sun light rays hit the zebras and from the zebras it goes to the water surface where the image is formed".*

Question 2 is one the questions that was well-answered in the post-test compared to the pre-test. It was about the reflection of an image on the surface of water whereby learners were expected to choose the correct answer from list of options (A. Reflection, B. Refraction, C. Dispersion, and D. Diffraction). See Figure 5 below.



Figure 5: Picture extracted from question 2 in pre-test and post-test

Most learners chose the correct answer (A. Reflection) and provided the correct explanations for their choices. It is based on this evidence that I concur with Stapleton and Thompson (2008) as they relate

sense-making to cognition focusing on how individual learners use their mental abilities to internalise the learning contents in order to make meanings out of them. This is what happened in the context of this study, as learners were influenced to internalise the topic *light* during the ASEI interventions so that they could make meaning in the post-test. This is also supported by the view of Bruner (1960), who argues that learners, as active constructors of their own knowledge, are more capable of understanding complex information.

The learners' responses from the stimulated recall interview based on their answers from the pre-test indicated that most learners were able to construct knowledge. Learners made meaning in most of the answers. The following are the samples of learners' responses from question 7 in the stimulated recall interview (Appendix D):

L2: *“Because the pencil did not move, so the image stays where it is. If the pencil was moved, then the image should also move”.*

L3: *“The change in the location of the source of light does not change the size and shape of the image in the plane mirror”.*

This evidence of learners' explanations is based on Bruner (1957), who points out that thinking is the primary outcome of the cognitive development resulting from new learning experiences of intellectual mind. This interview was conducted before the intervention, thus these explanations were individual learners' own thinking.

Although learners provided more correct answers in the post-test, they also provided correct answers in a few questions in the pre-test (Appendix G) using their prior knowledge. Learners' prior knowledge can be influenced by their social interaction in the community and previous school grades. This is supported by Vygotsky (1978), who believes that learners learn scientific concepts better through social collaborations with other knowledgeable individuals rather than through direct instructions.

4.6 Concluding remarks

In this chapter I analysed, presented and discussed data gathered from the pre-test, post-test, stimulated recall interview and questionnaires to explore how Grade 11 physical science learners make sense of the topic light. The data from pre-test and post-test were quantitatively analysed, presented and discussed while the data from learners' explanatory answers from the pre-test and post-test as well as questionnaires and stimulated recall interview were qualitatively analysed, presented

and discussed. All data were discussed in relation to answering the research sub-questions 1, 2, and 3.

The comparison between learners' results from pre-test and post-test showed a positive improvement as a result of the ASEI teaching intervention. For the qualitative result analysis, three main themes emerged from the data: learners' perceptions of the topic light; linking science concepts to everyday life; and construction of knowledge.

In the next chapter, the qualitative data presentation, analysis and discussion (phase two) from video-taped lesson observations and stimulated recall interviews are presented.

CHAPTER FIVE: DATA PRESENTATION, ANALYSIS, AND DISCUSSION (PHASE TWO)

5.1 Introduction

In this chapter I present, analyse and discuss qualitative data generated from the ASEI lesson observations and video-taped stimulated focus group interviews. The data sought to answer the following research sub-questions:

- What are the Grade 11 Physical Science learners' conceptions and experiences of the topic light before and after ASEI-PDSI teaching intervention was implemented?
- How does an ASEI-PDSI teaching intervention influence Grade 11 Physical Science learners' conceptual understandings of the topic light?
- What factors enable or constrain Grade 11 Physical Science learners to make sense of the topic *light*?

The same themes and supporting theory/literature used to discuss qualitative data in Chapter 4 were used to discuss data in this chapter as well for seeking answers to the above research sub-questions (see Chapter 4, Table 9).

5.2 Lesson observation

Observation was one of the data-gathering techniques used in this study. It offered me an opportunity to gather 'live' data occurring in a social situation, which in this case was a classroom (see Section 3.5.5). It further enabled me to explore how learners made sense of the topic *light* through ASEI lesson intervention, which was the focus of this study.

I was able to observe learners' conceptual understanding and factors that enable or constrain sense making. After every lesson, a focus group stimulated-recall interview was conducted to probe further explanations from learners. Three lessons were observed (see Lesson plans 1-3 in Appendix E). Each lesson lasted for 45 minutes. Lesson 3 was a double period lesson of about 90 minutes. The data presented here are from the video-taped lessons as well as from my field notes.

5.2.1 Observation of lesson 1 (45min)

Key: Mr B=Teacher

GR = Group: GR1 (group 1), GR2 (group 2), GR3 (group 3), GR4 (group 4), GR5 (group 5)

This lesson was about reflection of light.

In step 1, Mr B started the lesson by asking learners to discuss briefly how light enables our eyes to see things around us. He further asked them to state the phenomenon whereby light enables eyes to see things.

In five groups consisting of four, learners presented their discussions as follows:

GR 1: *“light bump on object and reflected back to our eyes to see objects”*.

GR 2 *“light hit things so that we can see them”*.

GR3: *“light from objects comes to our eyes to our eyes so that we can see them”*.

GR 4: *“light comes from sources travel to our eyes and from there to object to be visible”*.

GR5: *“light hit the object comes to our eyes and our eyes see the object”*.

Learners in GR 1, 3 and 5 provided correct explanations as to how reflection of light enables eyes to see object. All five groups presented that it is the reflection of light that enables the eyes to see things around us. However, most of them could not state that light come from the source to the object and get reflected to the eyes. This is slight evidence that some learners’ prior knowledge enabled them to make sense of the classroom science. This was an introduction to assess learners’ prior knowledge. These findings are in agreement with Srikantaih (2005), who refers to prior knowledge as experiential knowledge that learners bring to school and which influences how they make sense of the learning contents. Similarly, Stears et al. (2006) recognise that to build on learners’ experiences it is vital to connect the science known by learners to the one offered in the classroom. In this context, the teacher built on learners’ prior knowledge to lead them to the lesson topic.

In step 2, learners (5 groups of four) were provided with the plane mirrors to do the following observations:

- (c) Characteristics of image of a cup in the mirror; and
- (d) Closing their left eyes and observe their images in the mirror

Learners presented the characteristics of image in the mirror as follow:

“Same size as object”.

“Same distance from the mirror as object.”

“Virtual image”.

“Same colour as object”.

“The cup handle appear to be on light side in the mirror while on the object it appear on left side”.

When they closed the left eyes, they observed that in the mirror, it appears that the right eye was closed. This was evidence that learners made sense in this activity. Thus, these findings support the findings of Sutchcliffe and Weick (2005), who agree that learners’ actions and interpretations of learning content determine how they make sense of the science concepts.

Figure 6 below shows learners writing the characteristics of image in the mirror on their worksheets after the observation.



Figure 6: Learners working in group sketching the drawing on reflection after the observation of image in the mirror

These practical activities were done to enable learners to make sense of the characteristics of images in the plane mirror. Apart from practical activities, learners were further asked to make sketched drawings indicating how the reflection of light enables their eyes to see the image of a cup in the plane mirror. This activity was designed to explore how learners make sense of the concepts through observation and their drawings confirmed whether they were making sense or not.

Figure 7 below shows the sample of learners’ sketched drawings on the chalkboard.



Figure 7: Learners' sketched drawings of reflection

Although learners know that things can be seen due to reflection of light, based on their drawings, there was evidence that they had misconceptions that the light hits the image in the mirror and is reflected to the object. This could be the reason indicated by Roschelle (1995) and Meyer (2004) that it is the role of the teacher to clear the misconceptions and non-scientific beliefs learners bring to school. The drawings on the chalkboard revealed that learners had misconceptions that need to be corrected.

In step 3, the classroom was darkened by switching off the light bulbs and the windows and door were closed with fitted curtains. Learners were provided with torches and asked where to aim the torch flash if they wanted to see the image of the yellow sticker placed on their chests in the plane mirror.

The majority of learners (70%) were seen pointing the torch flash to the mirror. When one of them was asked whether she was able to see image of the sticker as she pointed the torch flash light to the mirror, she replied "*I cannot see the image of this paper because the light from the mirror hit my eyes*". This activity enabled the majority of learners to realise that they were supposed to point the torch flash light toward the yellow sticker in the chest for them to see its image in the mirror. These findings are similar to that of John (2014), who reported that most learners could not identify the ray of light from the torch to the object and be reflected by the mirror to the eyes so that the image can be seen.

At the end of this step learners were assessed by Mr B, who asked them to draw concept maps showing all scientific concepts that emerged from lesson topic 'reflection' of *light*.

Group representatives presented their mind maps consisting of concepts such as:

“Reflected ray”, “Source of light”, “formation of image”, “light help us to see”, “light travel in straight line”, “Same size as object”, “the image in the mirror”, “virtual”, “same distance”, “angle of incidence”, “angle of reflection”, “light heat object for you to see the image”. “Laterally inverted”, “light path”

Based on the learners' responses, there was evidence that the practical activity influenced learners' sense making in this topic. These findings concur with Millar, Marechal and Tiberghien's (1998) findings which support that practical work in teaching and learning activities engages learners in handling or observing real object or materials that can enhance learning. This is actually what I observed as learners were handling mirrors and observed the image they were to draw an informed conclusion from the evidence of what they had seen. In addition, these findings corroborate with those of Millar's (2010), who recommends that practical work helps students to develop their understanding of science, appreciate that science is based on evidence and acquire hands-on skills that are essential if students are to progress in science. It is also supported by Forbes (2008), who believes that practical activities enable learners to make sense of science through empirical evidences. This is actually what had transpired in this lesson.

In step 4, the teacher asked learners to state the applications of reflection of light in everyday life. Individual learners provided answers such as:

“Used by car drivers and motorists to see behinds”; “Used in dressing rooms in shops”; “Used by doctors in hospital”; “Used by people to see things around them in their environment”; “Used by plants to make their own food”.

This activity was intended to explore how learners make sense of the topic *light* by linking the classroom science to their everyday life experiences as proposed by Oloruntegbe and Ikpe (2011) as well to develop the conceptual understanding of the reflection light. It was evident that those learners had prior knowledge on the application of reflection light in everyday life in relation to the uses of mirrors. The similar view to these findings was highlighted by Mukwambo (2012), who expresses that learners construct meaning of concepts taught if prior knowledge is taken into account. It is also realised by Ryder (2001) that prior knowledge fosters a theoretical shift to viewing learning as conceptual change. Through the integration of their prior knowledge in this context, learners could

see the relationship between their experiences and the classroom science. Mr B concluded this lesson by reading the rationale of this lesson to the learners and he said:

“Reflection of light is used in daily life by vehicle drivers to see what is behind them using the mirror, by dentist to examine teeth and in the mouth, fitting rooms in shops, hair salons and barber shops, submarine etc.”.

The rationale was stated for learners to recognise the importance of the topic light in their everyday life. Through observation of lesson 1, I could witness that learners had prior knowledge which is scientific and some misconceptions.

5.2.2 Observation of lesson 2 (45min)

This lesson was about refraction of light. In step1 the teacher introduced the lesson by linking it to lesson one (reflection of light). In the introduction, he provided learners with the following objects: piece of wooden plank, silver plate, and a mirror. He asked learners to state which of those objects are able to reflect light rays and they should explain their answers. Below are the samples of some learners' answers:

“Mirror because it is smooth and shinny”.

“Mirror and silver plate because they have smooth surfaces and shiny”.

“Mirror because it does not absorb light, but reflects all the light rays”.

One of the learners opposed the answers provided by others and she said *“No sir! in the previous lesson we learn that all things are seen because they reflect light, it means wood, silver plate and mirror, all reflect light”.*

Through this activity, I observed that many learners had misconceptions that only shiny objects are able to reflect light, thus in their answers, they only mentioned that the mirror or silver plate are able to reflect light. In similar findings, Roschelle (1995) suggests that prior knowledge can produce mistakes.

In step 2 the teacher provided learners with bowls of water to observe their images and explain the phenomenon that generates their images in water. In their groups, learners provided the following answers from their observations:

GR1: *“Our faces and image in water are facing each other, and this is refraction”.*

GR2: *“The image is the same as the original body, but it is facing downward on the other side in water and this process is refraction because the image is caused by light that bend when enter the water”*.

GR3: *“The image is the same as our body, but is not upright like for the mirror, it is facing like downward and I think it is reflection because water is shinny like mirror”*.

GR4: *“Light comes from the source and then it hits your body , also hits in water and reflected back to the eyes , so that can see your image in the water”*.

GR5: *“Light rays hit my body and reflected to water in the bowls so that I can see my image in water”*.

In this activity I observed that some learners (GR1 and GR2) couldn't make sense of it. They believed that the phenomenon that generates the inverted image in water is refraction. It is evidence that they provided incorrect answers and explanations. They indicated that their images appear in water due to refraction of light. This activity was designed to explore how learners make sense of the reflection by water by linking it to the reflection by plane mirror covered in the previous lesson (lesson 1). Based on the learners' answers I could observe that prior knowledge is one of the factors that constrains learners' sense making in the topic *light*. Their answers were influenced by their background experiences on how they believe that only shiny surfaces reflect light. These findings concur with Eaton et al. (1986) as they indicted that learners believe that light only illuminates the surface, object or area to allow the eye to see. These are misconceptions caused by the way the learners view the image in water.

In step 3 the teacher provided learners with containers of clean water and coins. Learners observed the coin in the container without water and later they added water and observed the coin in the water. Learners were expected to explain their observations in terms of the image positions and its depth. Figure 8 below shows learners observing the coin in the container of water.



Figure 8: Learners observing the coin in water

Below are the samples of learners' responses from this activity:

GR1: "The coin is on top of the water and the image is down".

GR2: "The coin under the water seem to be seen on top of water compared to the one in the container without water".

GR3: "The position of the coin in water it seems like floating on top of water and the depth decrease".

GR4 "The coin looks bigger than normal when you are observing it under water and it looks near the water surface but it is underwater".

GR5: "The actual position of coin is at the base of the container but after the water is added, the coin's position is at the top of the water and the depth looks near compared to the real object/coin depth".

Based on learners' presentation in this activity, there was an indication that learners in GR4 and GR5 made sense of this experiment although they did not use the required science language (concepts) such as real depth, apparent depth, image and real object. They used everyday language (BICS) instead of academic language (CALP) as highlighted by Kamini (2001). In this context the practical activity influenced learners to give meanings to what they observed. This finding is in line with Mukwambo (2012), who supports that practical activity has a social constructivist's character as it allows learners to interact with each other while the teacher is facilitating the session. McRobbie and Tobin (1997) also support the concept that individual learners are able to make sense of the learning activities through social interactions. This is what had happened during the practical activity when learners were doing group work.

In step 4 Mr B asked learners to sketch the diagram with arrows to show how the rays of light travel from the coin under water into their eyes. Figure 9 below shows an example of the learners' diagrams:

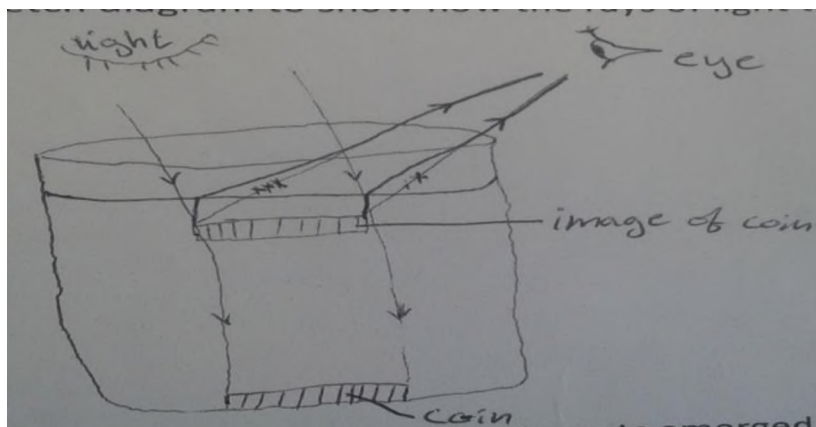


Figure 9: Sketched drawing on refraction

Based on the drawing, I observed that learners had an idea that the image appears shallower (apparent depth) while the coin is deeper although their diagrams were not completed with all labels. The findings in this activity resonate with Mukwambo's (2012) asserts on that some properties of practical work are that it is a medium of communicating ideas and can be achieved graphically, pictorially or symbolically. It is due to this background that learners presented their findings in form of diagram to confirm how they made sense in this activity.

In step 5 Mr B asked learners to compare the density of water with that of air and how it affects the speed of light that result on the refraction of light. In responding to that question, some learners provided answers such as the following examples:

"The speed of light is faster in air than in water because water is thick".

"Light travels faster in air than in water because the particles of air are far apart while the particles in water are close together; the particles block the movement of light rays".

Based on the examples of learners' explanations, there was an indication that they had knowledge about the speed of light in different mediums due to different density that can lead to refraction of light as it moves from one medium to another. However, some learners' explanations were not clear as they did not mention which medium is denser than the other or has more particles than the other. In addition, learners had slight misconceptions that particles block the movement of light rather than reducing the speed of light.

Although there was no practical activity conducted to answer this question, I noticed that there was knowledge construction in responding to this question. Learners' responses to this question were based on their own thinking, which is supported by Bruner (1957), who points out that thinking is the primary outcome of cognitive development resulting from new learning experiences of an intelligent mind. It is also advocated by Changeiywo et al. (2013), who recommend that the ASEI principle is that learners do not simply copy the world; rather they construct their own meaning of it.

In step 6 the teacher provided learners with convex lenses and let them go outside to observe how they affect the rays of light from the sun. After their observations, learners provided answers such as the following examples:

“They bend light to meet and make a spot at one point that can burn the paper”.

“They make light meet at a point and it burns something”.

This observation enables learners to understand how the convex lenses affect the parallel rays of light; however they used BICS instead of CALP as an indication that they lack scientific language. They used words such as *“bend light”*, *“make light to meet at a point”* instead of using scientific concepts like converging light rays. It was evident here that learners made sense in this activity, however, the language used in their answers did not sound scientific. Although learners experienced difficulty in expressing their answers in scientific language, it was clear that the practical activity enabled them to find out how the convex lenses affect the parallel rays of light. This finding is in line with Woodley's (2009) who states that really effective practical activities enable learners to construct a bridge between what they can see and handle (hands-on) and scientific ideas that account for their observations (brains-on).

In step 6 Mr B asked learners to explain the properties of image formed by convex lenses. In their groups learners provided some of the following samples of their answers:

“Image is upside down”.

“If it is in the camera image can be printed out”.

It was evident that most learners were making sense of this activity as they provided the correct answers. Their responses were influenced by their prior knowledge from previous school grades or community since there was no experiment done on image by convex lenses in this lesson. It was realised by Mukwambo (2012) that engaging learners' prior everyday knowledge makes it easy for

students to start a discussion or team project. That is what happened when learners were engaged in discussion to come with their answers.

In step 7 Mr B defined the vacuum as an empty space. He then asked learners to explain why light travels faster in the vacuum than in other mediums. Learners provided answers such as:

“In the vacuum there are no particles to block the light”.

“Other mediums have particles that decrease the speed of light”.

“The vacuum speed up the movement of light”.

Learners’ responses indicated that some learners made sense while others couldn’t make sense when answering this question.

In step 8 learners were asked to draw a concept map showing all the scientific concepts that had emerged from this topic refraction. Learners’ mind maps consisted of the following concepts:

“Vacuum”, bend light, Travelling of light in different mediums”, Different mediums have different speed of light”, “ in deep water the speed decrease”, “observation of object in water”, real depth”, apparent depth”, “image”, different mediums”, “coin in water”, “depth, “position of object in the water”.

Learners’ concept maps indicated how learners developed the scientific conceptual understanding resulting in sense making of this topic. Some learners wrote sentences instead of the single concepts i.e. they explained concepts in their own words. However, some learners’ concept maps represented the correct science concepts that emerged from the lesson. In this context, I observed that language is one of the factors that constrained sense making as some learners wrote the explanations instead of science concepts. This is supported by Vygotsky (1978), who identifies that language as the most important psychological tool in mediation of learning. He indicates that language enables learners’ external experiences to be organised into thought. Ballenger, Hundicourt-Barnes, Rosebery, Ogonowski and Warren (2001) concur by indicating that social, cognitive and linguistic practices are some of the most common potential barriers that constrain learners’ sense-making of the scientific concepts.

At the end of this lesson, Mr B read the rationale of lesson. He explained, *“The refraction of light is important in our life as it can be applied in eye spectacles to correct eye defects and in many other*

industries". The purpose of read the rationale was to enable learners to recognise the need for learning such a topic.

5.2.3 Observation of lesson 3 (90min)

This lesson was about the continuation of reflection of light.

In step1 Mr B introduced this lesson by placing white, blue and black papers on the classroom wall and asked learners to find out which one of those papers can be easily seen and explain why and how. In their groups, learners provided the following examples of their responses:

GR1: *"White paper can be seen easily because it reflects more light"*.

GR2: *"White paper can be seen easily because it reflects more light and absorb little light"*.

GR3: *"White colour reflect light more than blue, and black, even in the night people who wear white clothes, we can see them even when they are tar"*.

GR4 *"White because, white colour is the best reflector of light"*.

The purpose of this activity was to explore learners' sense-making with regard to colours that reflect more light than others. Many of them correctly mentioned white paper as it reflected more light in comparison to other two colours and can, therefore, be easily seen in the darkness. This was evidence that learners used their prior knowledge to respond to this question. It was their prior knowledge that influenced them to provide some of this reasons. This is in line with Kasanda et al. (2005), who discovered that when taking into consideration the learning effect of the use of daily context in science teaching, the distinctions in the methods of skills and knowledge building in everyday and scientific domains needs to be recognised.

In step 2 learners were provided with a reflector jackets and were asked to discuss in groups why reflector jackets are used by people in industries such as mining, transport, construction and fishing. After a group discussion, learners provided the following responses:

GRI: *"If a mine happens to collapse, people can be easily seen by emergency rescue because of reflection of light from the jacket to their eyes"*.

GR2: *"When people walk near the road in night, the drivers can easily see them because they reflect light to their eyes and can avoid accident in the road"*.

GR3: “When the car is broken and driver is standing near the road, he can be seen easily by other road users because the jacket reflect light to their”.

GR4: “ If a person happen to fall off from the , he can be seen easily by others and be helped quickly from drowning in water because the reflector send light back to the eyes of people around”.

The purpose of this activity was to explore how learners linked the topic *light* to the uses and importance of reflection of light in everyday life. In this activity, learners provided the correct reasons linked to the uses of reflection for safety reasons in various industries. Hence, they made sense in responding to this activities based on their prior everyday knowledge. This is in agreement with Keogh and Naylor (2002), who affirm that good science teachers are those who teach for deep understanding by using students’ prior knowledge about science to guide lessons, providing experiences to test and challenge those ideas to help students arrive at complex understanding. In this context, prior knowledge was used for learners to recognise the importance of reflection for safety reason and then learners linked it to science curriculum.

In step 3 learners were further asked to list other sectors apart from mining, transport, construction and fishing, where clothes with reflectors are being worn and why. In responding to this question, individual learners provided answers such as the following examples:

“Traffic police officers, to be seen by drivers whey they are standing on the road, so that they cannot be pumped by vehicles as the reflect light to the eyes of the drivers”.

“People who work at the fuel filling stations, just for them to be seen easily drivers when approaching the filling station and also for the not to be bumped because they are visible”

“Journalists when working in area with conflicts like war zone, so that they can be seen and avoid to be killed by mistakes”.

The learners’ responses indicated that they had some prior knowledge on the importance and uses of reflection in a general context as they were able to support their answers by giving some examples and this is in line with Keogh and Naylor’s (2002) findings in their study. I observed most of the learners were making sense of this activity as influenced by their background experiences.

In step 4 learners, in their groups, placed a pencil in front of the mirror on the table. The pencil remained fixed and learners moved a little further from the mirror. The teacher asked learners to explain what happened to the location of the image of the pencil in the mirror. In this activity, first

learners predicted their answers before the practical activity. Below are the examples of learners' predictions:

“The image will move further from the mirror”.

“The image will move the same distance from the mirror, just as that of a person move on the other side”.

After the practical activity, learners confirmed that the location of the image remained unchanged because the pencil was not moved; it was only the learners who moved little further away from the mirror. This experiment enabled learners to correct their misconceptions in order for them to make sense of the learning topic. This is supported by Maselwa and Ngcoza (2003), who proposed that practical work, encourages learners at various stages of inquiry to predict explain, explore, observe and explain (PEEOE) particularly when they have freedom to direct and adapt the activities according to the questions which emerge from their own experiences. In her study, John (2014) found the same misconceptions with learners.

In step 5 the room was darkened; the lamp was raised a little higher. The pencil in front of the mirror remained fixed. Learners were asked to predict before the experiment and later to explain after the experiment what happened to the location of the image of the pencil in the mirror. Below are examples of some learners' predictions:

“The image will also move high”.

“The image will move up as the lamp is also moved up”.

After the experiment, learners highlighted that the image of the pencil remained the same since the image of the pencil remained at the same position because the mirror and the pencil were not moved; it was only the light source that was moved. These were the same findings John (2014) obtained from her study. This activity enabled learners to correct their misconceptions of this topic. Moreover, these findings also support those of Maselwa and Ngcoza's (2003) as they indicate that PEEOE approach can help learners to develop scientific concepts of a specific topic so as to make sense of science in general.

In step 6 the lamp was raised little higher. The pencil and the mirror remained fixed on the table. Learners were asked to predict before the experiment and explain after the experiment what happened to the height of the image of the pencil. Below are examples of learners' predictions:

“As the lamp is raised high the image the image will become taller”

“The image will grow taller depends on how high the lamp is raised up”.

After the experiment, learners confirmed that the height of the pencil remained the same because it was only the source of light that light that was moved, but the mirror and the pencil were not moved. These findings are similar to that of John (2014).

In step 7 the lamp and the mirror remained fixed; the pencil was moved a little further from the mirror. First learners were asked to make their predictions as to what would happen to the height of the image of the pencil in the mirror and later explain it after the practical activity. Learners made some of the following predictions:

“The image will look smaller because the light of the lamp is far”.

“The image will become shorter because the lamp is far from it”

“The image will be small because it is not clearly visible, because not all light will reach the mirror”.

After the activity learners confirmed that the height of the image remained the same because only the change in the height of object can affect its image in the mirror. These findings are the same to that of John (2014).

In step 8 learners were asked to draw the concept maps showing all the scientific concepts that had emerged from this lesson. Figure 11 below shows an example of a learners' concept map:

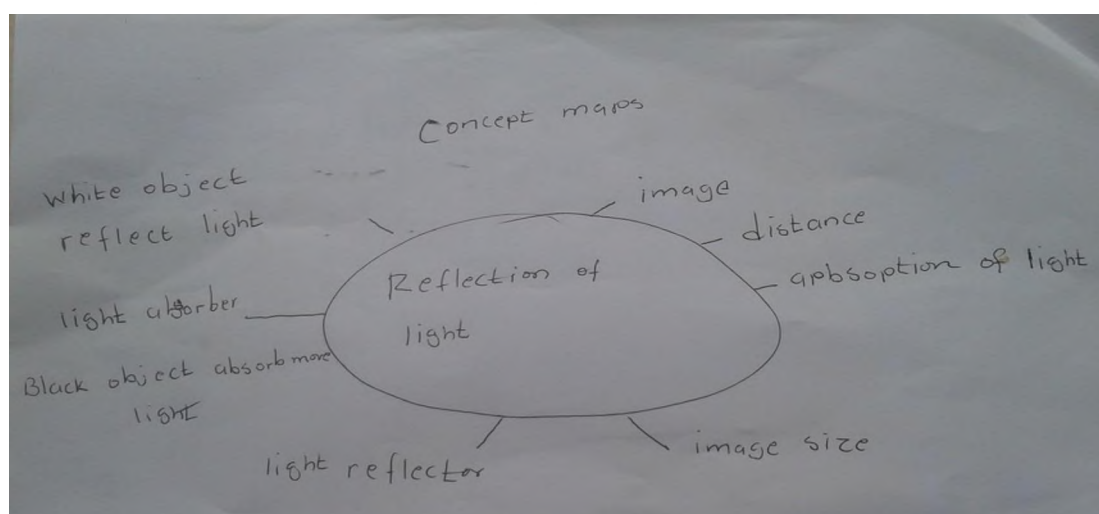


Figure 10: Learners' mind map on reflection of light

Based on the learners' concept maps, I confirmed that this lesson enabled most learners to develop a conceptual understanding of this lesson topic. Other learners' mind maps consisted of concepts such as:

“light reflection”, light absorber”, “absorption”, “distance”, “height”, “size”, “white object reflect more light”, black object absorbs most light”.

The drawing of mind maps confirm the learners' sense making as indicated by Forbes (2008), who presents that making predictions, fair testing, measurement, developing tables, the construction and use graphs and charts, explaining results and evaluating investigations is the evidence of sense making.

At the end of this lesson, Mr B highlighted the rationale of the lesson. He stated that *“reflection of light is applied in industries such as mining, transport, construction, etc., for safety reasons”.*

The findings from lesson 3 revealed that the practical activity enabled learners to prove their hypothesis since first they were expected to make the predictions and later on they had an opportunity to correct their own misconceptions. This was indicated by Millar (2010), who found that carrying out of scientific projects or investigations may help learners to improve their cognitive and creative skills. The findings from this lesson are also supported by Ramsden (1994), who states that for curiosity to be aroused and stimulated, there is a need for the teacher to position activities and experiments in the context of everyday life experiences of learners. For instance, I was able to see that learners were interested in participating in the practical activities.

The ASEI lessons are in line with Bruner (1960), who posits that human beings learn through three modes of representation: enactive (actions-based); iconic (visually-stored images or mental pictures); and symbolic (language-based in words and symbols). The ASEI lessons integrate practical activities that accommodate all three modes of representation.

5.3 Stimulated recall interview

Key: R: Researcher; Ls: Learners; L: Learner

After every lesson, I watched the videos and conducted a stimulated recall interview with the entire class of 22 learners who participated in this study. The learners were seated in their groups and the purpose of the interview was to probe more explanations based on their actions, explanations, answers and areas of concerns that were not clear during the lesson presentations (see Appendix J).

5.3.1 Lesson 1 stimulated recall interview

Based on learners' lesson explanations, learners indicated that for the object to be seen in the darkness light from the candle should be directed to the object and the reflected back to the eyes so that it can be seen. For example, one of the learners said that *"ok, I wanted to say in darkness, you cannot see things, but when you light the candle things can be seen"*. They learned that luminous objects are needed to provide light that be reflected by illuminated for them to be seen. This was an indication that learners made sense of this concept.

Learners had some misconceptions about how a mirror works in reflecting light for image to be seen. Below are examples of the conversations during the interview.

R: *"Most of you were seen pointing the torch flash toward the mirror for you to see the image of yellow sticker on your chest in the mirror. What was your intention to point it in that way"?*

L: *We thought the mirror; the mirror should be visible for things to be seen in it.*

It was based on this learner's observed action that one of the learners realised that the flashlight should be aimed at the object that needs to be seen in the mirror but not to point it at the mirror as it was a case during the lesson. When, learners were asked if there were other objects that can be seen directly not depending on the reflection of light from other sources, the majority learners indicated that all things are visible due to reflection of light. However, one of the learners raised her hand up and said *"sorry sir, the sun produces its own light we can see it directly, it does not depend on light from other sources in order to be seen"*. It was based on this reason that learners came to understand that luminous objects are the sources of light and they are visible on their own.

5.3.2 Lesson 2 stimulated recall interview

The interview conversation for lesson two was conducted as follows:

R: *"Explain what you meant when you say your image in a bowl of water is upside down"*.

L: *"Ok, I see my face and image face were facing each other, my body is upright but my image in water is facing downward"*.

It seems that learners thought that the image in water is different from the image reflected in the mirror.

R: *"You compared the surface of water with that of the plane mirror. What do you mean by that"?*

L: *“The surface of water is very shiny and smooth, ok that image is not a real object under water, if you go into water, and you cannot touch it there, just like image in mirror”.*

In this case, learners made sense in answering this question as they compared the image in the mirror with the image reflected in water to be similar.

R: *“You said you see two coins under water, and then you shake on your head. What did you want to say”?*

L: *“Sir! aaye! I was confused I do not which one of the two coins is the image or object”.*

There was an indication that some learners could not find the difference between the real object and the image of the object in water, hence they were not really making sense in this activity.

R: *“Why did you put a ruler in the water although the teacher did tell you to do it? What was your intention and observation to do this”?*

L: *Mmh! I just wanted to show this one (pointing to another learner) that the ruler looks bending just like refraction of light as it enters the water”.*

In this context some learners indicated that they explored beyond the teachers’ instructions to construct meaning of the refraction of light.

5.3.3 Lesson 3 stimulated recall interview

The interview conversation for lesson three was conducted as follows:

R: *“When the lamp was raised a little higher while the pencil and mirror remain fixed, you predicted that the image of the pencil in the mirror would also move up. Why were you thinking that”?*

L: *“No, I though the image follow the movement of light, but I was wrong sir”.*

It was an indication that some learners reflected on their misconceptions and realised that their prior-knowledge had led them to make wrong and unscientific predictions.

R: *“When the lamp was raised a little higher while the pencil and mirror remained fixed. You predicted that the height of the image become taller. Why did think about this”?*

L: *“Sir! I am not sure, but during the sunrise and sunset, shadows of trees become longer”.*

Based on this learner's explanation I found that some learners do not understand the difference between image and shadow. These misconceptions constrained them from making sense in this activity.

R: "How did you relate shadow to the image in the mirror"?

L: Sir! I think shadows and images are all caused by light. Oh, it's confusing me".

This was evidence that learners could not make sense of this activity as they did not know that shadow and image are scientifically different.

I observed that through these three stimulated recall interviews (SRIs), individual learners were able to explain their answers, actions and behaviours. Simultaneously, they were also correcting their own mistakes and misconceptions that could prevent them from sense making in these lessons. I thus concur with Lyle (2003), who defines stimulated recall (SR) as a family of introspective procedures through which cognitive process can be investigated by inviting participants to recall, when prompted by a video sequence their concurrent thinking during that event. These findings support both cognitive and social constructivism. With regards to cognitive constructivism, learners explained their own individual actions based on their own thinking to provide the correct answers. This is in line with Bruner (1960), who argues that as active constructors of their own knowledge, learners are more capable of understanding complex information.

With regards to social constructivism, in this context it was a focus group where learners were working as group. Their answers emerged from their group discussions with a view that they were learning through collaboration. This supports Moll (2002), who discusses social constructivism as a learning theory which emphasizes that learning occurs as a result of social interaction with a knowledgeable individual. Through SRIs, I was able to find whether learners had made sense of the lesson topic or not as this was based on their answers.

5.4. Concluding remarks

This chapter provided the presentation, analysis and discussion of data from lessons observations and video-taped stimulated recall focus group interviews. Literature reviewed in chapter two was used as reference to support claims made in this chapter. The findings of the study revealed that learners' sense making of the topic *light* is influenced by their prior-knowledge, language and practical activity. It is evident that the ASEI teaching intervention improved learners' sense making of the topic *light*.

In the next chapter, I present a summary of the findings, and make some recommendations and conclusion.

CHAPTER SIX: SUMMARY OF FINDINGS, RECOMMENDATIONS AND CONCLUSION

6.1 Introduction

The main goal of this study was to explore how Grade 11 Physical Science learners make sense of the topic *light* using the ASEI-PDSI teaching approach. In Chapters Four and Five, I presented, analysed and discussed the findings of the quantitative and qualitative data generated from tests (pre-test and post-test), and the qualitative data generated from stimulated recall interview, questionnaire, lessons observations and video-taped stimulated recall focus group interview. In this chapter, I present the summary of the research findings, recommendations and areas for future research. The study sought to answer the following research sub-questions:

1. What are the Grade 11 Physical Science learners' conceptions and experiences of the topic *light* before and after an ASEI-PDSI teaching intervention was implemented?
2. How does an ASEI-PDSI teaching intervention influence Grade 11 Physical Science learners' conceptual understandings of the topic *light*?
3. What factors enable or constrain Grade 11 Physical Science learners to make sense of the topic *light*?

These research sub-questions helped to provide answers for my main research question:

How do Grade 11 Physical Science learners make sense of the topic *light* through an ASEI-PDSI teaching approach?

I also discuss my personal experiences throughout this research study and end with conclusion.

6.2 Summary of findings

Research sub-question 1:

What are Grade 11 Physical Science learners' conceptions and experiences of the topic *light* before and after an ASEI-PDSI teaching intervention was implemented

As reflected in the findings from the questionnaires, there was indication that most learners perceived topic *light* as an important topic. They indicated that it is important for them to learn about light in school with the view that light plays important roles in their daily life. The findings of the questionnaire further revealed that learners had a positive attitude and willingness towards the topic *light*.

Based on their prior knowledge, learners indicated the necessities of learning topic *light* in relation to their daily life experiences. It is regarded by Mukawambo (2012) as important to integrate and recognise learners' prior everyday knowledge and experiences in engaging learners into new situation. The findings from questionnaires revealed that learners' interests of the topic *light* are influenced by their prior knowledge. Meyer (2004) appreciates what learners already know and develops learning experiences that provide them with opportunities to use their knowledge to accommodate new skills and scientific knowledge for better understanding.

Furthermore, the learners' responses from the questionnaire indicated that they were able to link the science concepts to natural phenomenon. This was an indication that learners used their prior knowledge to link classroom science to natural phenomenon. Although learners' responses from questionnaires had shown that they recognised the importance and uses of light in everyday life, the pre-test results were clear that learners had little scientific experiences of the topic *light*. The results from the pre-test learners scores indicated that only 13.6% of learners reached 50% and above.

Research sub-question 2:

How does an ASEI-PDSI teaching approach influence Grade 11 Physical Science learners' conceptual understanding of the topic light?

After the ASEI teaching approach intervention, learners' conceptual understanding related to the topic *light* improved significantly. This is reflected in Table 9, as post-test results show an increase by 27% shifted from 35% in the pre-test to 62% in the post-test. These findings support Rotich and Mutisya (2013), who confirm that ASEI-PDSI is a possible development in science as it gives learners an opportunity to explore and satisfy their curiosity. In the post-test, most learners chose the correct answers in most questions and their explanations of their answers indicated sense-making of the topic *light*.

The ASEI teaching approach created a positive shift in terms of learners' sense making and knowledge construction. This was reflected in learners' responses during the lessons when they were expected to make several observations and respond to several questions.

Research sub-question 3:

What factors enable or constrain Grade 11 Physical Science learners to make sense of the topic light?

The findings of this study revealed that practical activities and an inclusion of learners' prior knowledge are some of the factors that enabled learners' sense making of the topic *light*. ASEI-PDSI

is a teaching approach whereby learners are actively involved in practical activities during the lesson. In the context of this study, the practical activities enabled learners to confirm the outcome of their observations and they were also able to correct their misconceptions.

Before the practical activities, learners were always asked to make their predictions of what could happen and later they confirmed their observations empirically. It was evident after each practical activity lesson that most learners managed to draw mind maps showing the correct scientific concepts that emerged from each lesson. In addition to the practical activities, the findings of this study revealed that learners' prior knowledge enabled them to make sense of the topic *light*. During the ASEI teaching, for instance, learners' prior knowledge was used as a starting point as well as throughout the lesson. It was based on their prior knowledge that the teacher built on the whole lesson as proposed by Kasanda et al. (2005), who emphasize the need to use learners' existing knowledge/skills and include learners' everyday experiences in order to introduce a topic.

As a result, the findings revealed that learners were able to link classroom science to natural phenomenon such as lunar eclipse, solar eclipse and rainbow. There was also evidence that learners used their prior knowledge to correctly explain how the reflection of light is used in various industries such as fishing, mining, construction and transport.

Although prior knowledge was identified as enabling sense making, the research findings also revealed that prior knowledge on the other hand constrained sense making of the topic *light*. Learners had several misconceptions about light which were influenced by their prior everyday knowledge. For example, learners had misconceptions that only shiny objects such as a mirror and silver plate are able to reflect, while objects such as wood cannot reflect light. Learners also believed that shadows and images are scientifically similar.

The research findings also revealed that the LoLT is another factor that constrained learners' sense making of the topic *light*. In the context of this study the LoLT was English as second language. There were wrong spellings of scientific words in some learners' responses in the pre-test. Such spelling mistakes were influenced by learners' English proficiency as they did not recognise that their spelling of concepts made the whole sentences to be senseless in such a way that they could not be understood scientifically.

6.3 Recommendations

The current research has generated further research possibilities. Particularly, it could be interesting to carry out further research on exploring how practical activities influence Grade 11 Physical Science learners' sense making of the topic *light* or alternatively investigating how practical activities improve Grade 11 Physical Science learners' conceptual understanding.

This study revealed that the ASEI teaching approach positively influenced learners' sense making of the topic *light*. Practical activities in ASEI lessons enhanced learners' collaborative learning as it promoted team work among learners although in some cases they had to carry out lesson tasks individually to assess individual learners' cognitive development. It is highlighted by Changeywoet al. (2013) that with the ASEI-PDSI approach, students are provided with opportunities to construct scientific knowledge through the interaction of their observations, prior knowledge and mental processes. The study thus recommends the ASEI approach should be used in science classrooms.

Learning becomes more interesting when practical activities and learners' prior knowledge are integrated. This is supported by Ramsden (1994), who indicates that for curiosity to be aroused and stimulated, there is a need for the teacher to position activities and experiments in the context of everyday life experiences of learners.

Lastly, I would like to suggest that similar studies should be conducted in other secondary schools in Ohangwena Region. Findings from such studies might emphasize the importance of the ASEI teaching approach so that it can be adopted and be used in all science schools in this region for academic improvement. Furthermore, I would like to recommend the use of ASEI in other topics in physical science as well as other related subjects.

6.4. Area of future research

I recommend that further research could be done on the same topic this study addressed. This could be done by adopting a quasi-experiment research design where one class is taught using ASEI teaching approach and another without. This could help to compare the result scores of learners taught Physical Science through the ASEI approach and those taught without the ASEI approach.

6.5. Limitations of the study

The result of this study is limited to Z Secondary School (pseudonym) in the Ohangwena region and therefore it cannot be generalised. Findings from one Grade 11 class only might not reflect a reality

of how all learners make sense of the topic *light* in Namibian schools. However, some insights on how learners make sense of the topic *light* were obtained from this case study.

Another limitation was that the use of video recording as a data gathering tool. I was responsible for both lesson observations while at the same time I was recording the video. There is a possibility that some learners' actions were not captured during the lessons. Although classroom windows were fitted with curtains, the quality of pictures in the video was affected by the sunshine since all the lessons took place in the afternoons.

6.6 Reflections and conclusion

Apart from the stated limitations of this study, I encountered a number of issues, challenges and new experiences during this research journey. Through observing lessons in the afternoon, learners sometimes used to be tired and hence they could not concentrate well during the lessons. In addition, Mr B also conducted lessons with Grade 12 part-time learners before the teaching of ASE lessons, thus on some days he suspended the ASE teaching just for him to get resting time. In that case I had to go back without collecting any data.

Sadly, at the beginning of the data collection process, the Physical Science teacher who was supposed to deliver all the ASE teaching approaches passed away in a car accident. Such a situation might have affected learners' psychologically. I had to seek the consent of another experienced Physical Science teacher (Mr B) at the same school who might not have the same expertise and enthusiasm as the one who deceased. So, it could be surmised that the changing of teacher participants might have affected the quality of the expected lessons that I observed.

Finally, in this case study using a mixed method approach on exploring how Grade 11 Physical Science learners make sense of the topic *light* seemed to address the stated goal of this study, I learned that practical activities and the inclusion of prior knowledge in ASE teaching approach influenced learners' sense making.

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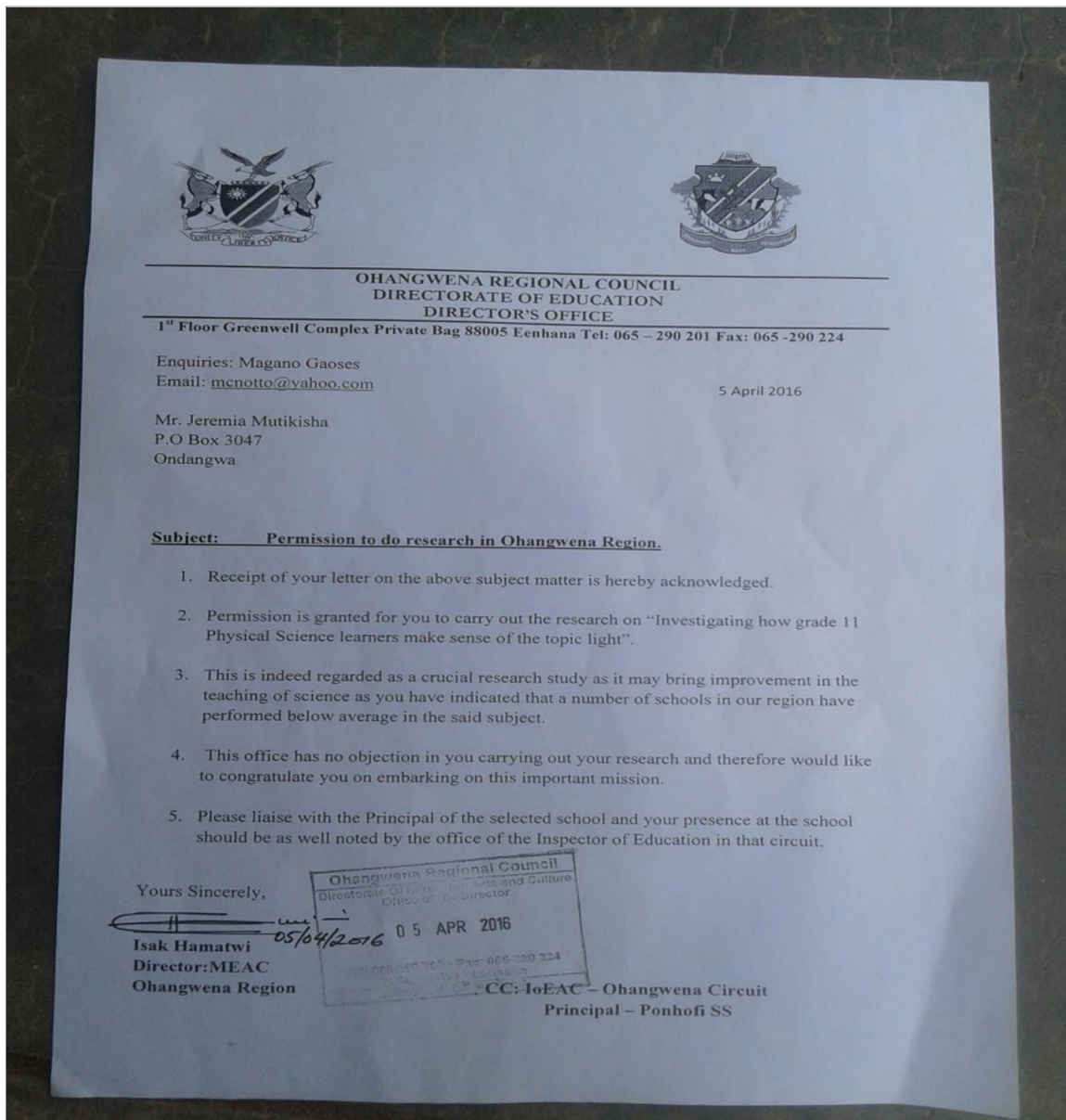
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APPENDICES

APPENDIX A: Permission letter from the regional director



APPENDIX B: Permission request letter to the principal



Enq:mutikisha@gmail.com

Cell: 0812121490

Ref: 25/2/9/8

TO: The Principal



Ohangwena Circuit, Ohangwena Region

Dear Sir

Re:Request for permission to conduct the educational research in the school

EDUCATION DEPARTMENT

Tel: +27 (0) 46 603 8383

Fax: +27 (0) 46 622 8028

PO Box 94, Grahamstown, 6140

I, **Nghidixumo Jeremia Mutikisha** student number **13M6823** currently doing a master of science education with Rhodes University, Grahamstown, South Africa. I am currently doing my second year and planning to carry my research study as from March 2016 up to the end of this academic year 2016.

I am writing this letter to kindly request your esteemed office to grant me the permission to conduct my research study at this school for this academic year 2016. My focus research area is **investigating how grade 11 physical science learners make sense of the topic light using discovery and experiment method.**

Attached, find the permission letter by the director of Education in Ohangwena region.

One grade 11 physical science teacher and one class group of grade 11 learners at school will be involved as research participants upon their consents are obtained. This study will not interrupt the normal teaching hours at school, therefore it will be carried in the afternoon. In addition, the study may benefit the participating teacher and learners as far as the learning and teaching of science are concerned.

Their participation in this research study is completely voluntary and they can withdraw at any time. The data collected in this study will be published as a Rhodes University half thesis. The identity of each participant and their views or contributions will be treated with a high degree of confidentiality and anonymity. The name of the school will not be reflected in the thesis for ethical reasons.

Sincerely

Mutikisha Nghidixumo Jeremia

Rhodes University

MEd in Science Education Student

Dr K. Ngcoza and Dr Jennifer Williams (Supervisors)

Rhodes University

ACCEPTED/NOT ACCEPTED

COMMENTS

Principal's Name.....

Signature.....

Date.....

APPENDIX C: Teacher's consent letter



RHODES UNIVERSITY
Grahamstown • 6140 • South Africa

EDUCATION DEPARTMENT
Tel: +27 (0) 46 603 8383
Fax: +27 (0) 46 622 8028
PO Box 94, Grahamstown, 6140
E-mail: education@ru.ac.za

18 April 2016

Dear Research Participant

Re: Participation in research on investigating how grade 11 physical science learners make sense of the topic light using discovery and experiment method.

Thank you for agreeing to be a research participant in my study. As per our discussion, my research area is 'Investigating how grade 11 physical science learners make sense of the topic light'.

The study will be conducted in **four** phases. The **first phase** requires learners to complete a questionnaire. The **second phase** involves learners answering pre test questions. The **third phase** of the study is the teaching intervention of four lessons using ASEI-PDSI teaching approach and experiment methods. The **fourth phase** requires learners to answer questions on the post test assessment after the teaching intervention.

Your participation in this research study is completely voluntary and you can withdraw at any time. The data collected in this study will be published as a Rhodes University half thesis. The identity of each participant and their views or contributions will be treated with a high degree of confidentiality and anonymity.

Sincerely

Nghidixumo Jeremia Mutikisha
Rhodes University
MEd in Science Education Student

Dr K. Ngcoza and Dr Jennifer Williams (Supervisor)
Rhodes University

I agree to participate in the research on condition that I can withdraw at any time.

Name... *Nghidixumo Jeremia Mutikisha*
Signature... *[Handwritten Signature]*
Contact number... *081 214 6662*

APPENDIX D: Parents' consent letter

Enq: Mutikisha N Jeremia

Po Box 3047

Cell: 08121490

Ondangwa

E-mail: mutikisha@gmail.com

14 April 2016

Dear Parent/Guardians for: [Omudali/Omutekuli wa:].....

Permission for being a participant [Ediminino loukwashilyo]

I Nghidixumo Jeremia Mutikisha, currently a Science teacher and principal of Nghiteke primary school in Ohangwena Circuit, Ohangwena Region. I am here by submitting my request to you as a parent or guardian, to permit your child to be a participant of my research study amongst others. [*Ame Nghidixumo Jeremia Mutikisha, omuhongi nondili yo omukulunhufikola pofikola ya Nghiteke primary school, ohandi indile nefimaneko linene epitikilo opo omuhongwa atumbulwa pombada akale umwe womovahongwa vahooolwa owina mokati kavakwawo.*]

These learners will participate in a science research study I am doing through Rhodes University where I am a student. The study aims at researching how grade 11 physical science learners make sense of the topic light. [*Ovahongwa ava ova hoololwa shinasha nokuninga omapekaapepo oshihongwa shoudindoli osho handiningi meilongo lange mo University ya Rhodes South Africa. Omapekaapeko okunasha noku tala nhee ovahongwa ta vauduko nawa oukwatya weenhe needjo douyelele.*]

Being members of this group, I believe it will be beneficial to this child in progressing well with understanding this subject in grade 12. [*Moku kala mongudu eyi oshina ouwa muhapu, owo tashi dulika uka kwafele okaana aka moku ke sheendifa nawa mondodo onhimulongo nambali (grade12).*]

I am therefore apologising in advance that, since this study will be conducted at school (Ponhofi ss) in the afternoon. Hence some learners, especially the non-hostel borders might not arrive on time at home. [*Ohandi yandje ombili, eshi tashi dulika omafiku amwe tave keya kwatoka omolwetomhelo eli kutya aishe otayi ningwa pofikola konima yeetundi.*]

Hence, I request you to indicate your choice by ticking in [✓] in the appropriate box below [Ulika epitikilo loye mu kamwe komuukololo ava.]

Agree [ndapitika]	
Not agree [Inandipitika]	

Signature [Eshaino]..... Date [Efiku].....

Your cooperation is highly appreciated.[Tangi kelongelo kumwe.]

Yours in education [weni melongo]

Mutikisha N Jeremia, Signature..... Date.....

APPENDIX E: Asei lesson plans

ASEI lesson plan 1

Date: 26-09-2016

Subject: Physical Science lesson 1
45 min

Duration:

Topic:Light
of learners: 22

Number

Sub-topic: Reflection of light

Rationale: Reflection of light is used in daily life by vehicle drivers to see what is behind them using the mirror, by dentist to examine teeth and in the mouth, used fitting rooms in shops, hair salons and barber shops etc.

Objectives: By the end of the lessons learners, should be able to define reflection of light, describe the characteristics of image by the mirror, draw the sketch diagram to show how reflection of light

enables the person's eye to see something and discuss the applications of reflection of light in everyday life.

Prior Knowledge:

Pre-requisite knowledge: and skills

- Reflection
- Reflection by plan mirror and surface area of clean water
- Sketch drawing of reflection of light
- characteristics of image by plane mirror

Teaching and learning resources/ materials

- Plane mirrors
- Torches
- yellow stickers

Lesson stages/steps	Teaching and learning activities	Learning point	Remarks
Introduction (5min)	<p>Initial questions based on Prior knowledge:</p> <ol style="list-style-type: none"> 1. Discuss briefly how light enables our eyes to see things around us. 2. How do we call the phenomenon whereby light enables eyes to see the objects? By using your own words define that phenomenon. 	Concept reflection of light	

<p>Lesson Development (20min)</p> <p>Phase 1</p>	<p>1.(a) Learners are provided with mirrors to do the following observations and explain their observations:</p> <p>(i) their images in the mirrors</p> <p>(ii) closing the left eye and they observe the change on the image</p> <p>(b)Based on the observations, draw a sketched drawing indicate how the reflected light enables their eyes to see their images in the mirror</p> <p>2. A cup is placed in front of the mirror, learners sit in front perpendicular to the mirror. Describe the characteristics of the image of the cup in the mirror.</p>	<p>Characteristics of Image by a plane mirror due to reflection of light</p>	
<p>Phase 2 (10 min)</p>	<p>In a darkened classroom, learners are provided with torches and asked where to aim the torch flash if they want to see the image of the yellow sticker on their chests in the mirror? And draw a sketched drawing with arrows showing how reflected light from the torch flash enables the eye to see the image of the sticker on the chest.</p>	<p>Image by a plane mirror due to reflection of light</p>	
<p>Evaluation (10min)</p>	<p>1. Draw a concept map showing all scientific concepts emerged from this lessons topic reflection of light.</p>	<p>Scientific concepts under the topic light</p>	

Conclusion/ consolidation (5min)	2.State the applications of reflection of light in everyday life	Uses of the reflection of light	
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ASEI lesson plan 2

ASEI Lesson plan

Date:

28-09-2016

Subject: Physical Science lesson two

Duration:

45 min

Topic: Light

Number

of learners: 22

Sub-topic: Reflection & Refraction of light

Rationale: Reflection of light is used in daily life by vehicle drivers to see what is behind them using the mirror, by dentist to examine teeth and in the mouth, used fitting rooms in shops, hair salons and barber shops etc. The refraction of light is applied in eye spectacles to correct eye defects.

Objectives: By the end of the lessons learners, should be able to define refraction of light, describe the characteristics of image by the convex lenses. Draw the sketch drawing of refraction of light showing how eye sees the object under water.

Prior Knowledge:

Pre-requisite knowledge: and skills

-Reflection & Refraction

- Relating the reflection by plan mirror to that of the surface area of clean water

-Some materials reflect light than others

-All materials reflect light in order for them to be seen

Teaching and learning resources/ materials

- Wood, Silver plate and mirror

-Bowls with clean water

-Convex lenses

- Containers with clean water and coins

Lesson stages/steps	Teaching and learning activities	Learning point	Remarks
Introduction (5 min)	<p>Initial questions based on Prior knowledge:</p> <ol style="list-style-type: none"> Learners observe the following objects: wood, silver plate and mirror. They state which of those objects are able to reflect the light rays? And explain why? 	All objects reflect light in order for them to be seen	
Lesson Development (20min) Phase 1	<ol style="list-style-type: none"> Learners are provided with bowls of water to observe their image and explain the phenomenon that generates their image in the water. Learners are provided with the bowls of water. They observe the 	Application of refraction and reflection of light in	

	<p>coin under the water and explain their observation in terms of its position.</p> <p>3. Draw a sketch diagram to how the rays of light travels from the coin under water into their eyes.</p> <p>4. Learners compare the density of water with that of air and how they affect the speed of light that lead to the refraction of light.</p>	real life situation.	
Phase 2 (10 min)	<p>1. Learners are provided with the convex lenses and observe how it affects the rays of light from the sun.</p> <p>2. Learners explain the properties of image formed by the lenses of the camera</p>	<p>Application of refraction of light in everyday life.</p> <p>Properties of image by plane mirror</p>	
Evaluation (5 min)	<p>2. Draw a mind map showing all scientific concepts emerged from this lesson topic refraction of light.</p>	Scientific concepts	

		under the topic light	
Conclusion/ consolidation (5min)	1. A vacuum is an empty space, explain why light travel faster in the vacuum than in other mediums?	Speed of light	

ASEI lesson plan 3

ASEI Lesson plan

Date:

06-10-2016

Subject: Physical Science lesson 3

Duration:

90 min

Topic: Light

Number

of learners: 22

Sub-topic: Reflection of light

Rationale: Reflection of light is used in daily life by vehicle drivers to see what is behind them using the mirror, by dentist to examine teeth and in the mouth, used fitting rooms in shops, hair salons and barber shops and reflector jackets and other different types of reflectors are used by people in industries such as mining, transport, construction, and fishing for them to be seen easily even in danger zones for safety reasons and to avoid accidents.

Objectives: By the end of this lesson learners should be able to explain why some object colours can be able easily seen in darkness than others, whether the following changes affect the characteristics of image in the plane mirror: position of object, the distance between object and mirror, the position of the source of light and the position of the person observing the image.

Prior Knowledge:**Pre-requisite knowledge: and skills**

- Reflection
- Relating the reflection by plan mirror to that of the surface area of clean water
- Some materials reflect light than others
- All materials reflect light in order for them to be seen

Teaching and learning resources/ materials

- Plane mirrors
- reflector jackets
- Coloured papers (white, blue & black)
- Objects such as marker pens, pencils containers

Lesson stages/steps	Teaching and learning activities	Learning point	Remarks
Introduction (10min)	Initial questions based on Prior knowledge: 1. In a darkened classroom, white, blue and black papers are place on the wall. Learners observe to find out which of the papers can be easily seen and explain why and how?	Some colours reflect light than others	

<p>Lesson Development (20min)</p> <p>Phase 1</p>	<p>5. Learners look at the reflector jacket. Discuss in groups why reflector jackets are used by people in industries such as mining, transport, construction, and fishing.</p> <p>6. Apart from the above mentioned industries, in groups, learners list down other sectors where the clothes with reflectors are being worn? And why?</p>	<p>Application of reflection in real life situation.</p>	
<p>Phase 2 (40 min)</p>	<p>3. In pair, learners are sitting in front of the mirror on top of the table and the pencil is placed in front of the mirror. Learners observe the location of image seen by both of them when sitting perpendicular to the mirror and pencil. Explain if there is a difference in the position of the image seen by both learners.</p>		

	<p>4. The pencil is moved to the right beyond the region perpendicular to the mirror. Both learners observe the image and draw their conclusions.</p> <p>5. (a) A pencil is placed in front of the mirror on top of the table. The pencil remains fixed. The learner moves little further from the mirror. Explain, what happen to the location of the image of the pencil in the mirror?</p> <p>(b)The room is darkened; if the lamp is raised a little higher explain what happen to the location of the image of the pencil?</p> <p>(c)If the lamp is raised little higher explain, what happen to the height of the image of pencil?</p> <p>(d)The lamp remain fixed, the pencil is moved a little further from the mirror. Observe what happen to the height of the image of the pencil?</p>		
<p>Evaluation (15min)</p>	<p>3. Draw a concept map showing all scientific concepts emerged from this lesson topic reflection of light.</p>	<p>Scientific concepts under the topic light</p>	

Conclusion/ consolidation (5min)	2. Explain how the change in position of the light source may affect the image.	Uses of the reflection of light	
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APPENDIX F: Collated data from learners' questionnaire

Question 1: In your view, do you think it is necessary to learn about light in school or not? Explain your answer.

L1	Yes it is necessary because we need to know more about light and its work. And necessary because light is the one used by people to see what they want during night
L2	Yes it is necessary to learn about light in schools because it is part of our education we learned about the source of light as from the sun. We may use this source for different purposes like when we are driving people use mirror on the car to see what is behind
L3	I think it is not important to learn this topic because it is part of everyday life. I said so with a reason behind that in all days of life we use light as a source of energy for use to be able to see during night so I think it's already familiar to everyone and I don't think it is important to be learnt again.
L4	Yes Because things that we learn in light are those that we use in everyday life. In this way we have to learn things like: The law of reflection in plane mirror: Laws like: the distance of incidence is equal to the angle of reflection; The size of the image is equal to the size of the object. All the things that I mentioned above are under the topic light.
L5	Yes its necessary because is only in school you can learn what are the important of light, how it travel. If there was no light we cannot see well during night time.
L6	It is very important, because it teaches me the importance of light and how light travels in different medium objects in every day life therefore I gain more knowledge and information about light

L7	Yes, Its necessary, because though learning about light helps us to develop some skills on how to use light instrument when we come across them. Its necessary because at the end of the day some learners might work with electricity which provides light so they need to learn more about light. Through learning about light, we will be familiar with all instruments that uses light and to know where light comes from.
L8	Yes because we need to know more about light when we still at school because there is no light no one can going to have enough energy.
L9	Yes ,because it help me and my fellow learner how light are used to produced and gave us advantage and disadvantage of light. It also help some of learner that who are having sight deficiency either night or day.
L10	Of course yes; it is very much urgent for us to learn about light in school so that we will know that what is the source of light in reality. Also, for us to be taught light in our life. Perhaps we handle light or how it can be conserved especially light from electricity at our houses & wherever it is.
L11	Yes because, Learners should be taught so that they may know how light is and how it travels in different ways. To know the colour of light and how it may pass through objects.
L12	Yes, because it helps more learners in charge of its charger, make the school learners to know how to be careful of it. Mostly the sources that use light from other source e.g moon and cup that is regarding as illuminated objects. It is necessary to learn about light in school because it helps learners on ways the light travel just for them to have idea and have a brief on it and pass information to the individuals.
L13	I think it is necessary because we just knew that there is light and we didn't really knew that light travel faster than sound. All children will really like this topic because they will learn how light is reflected, how a rain bow is formed when light travel through a triangular prism.
L14	Very much important to learn about it because we people need to know the advantage and disadvantage of light, to know how to control they light especially when you are

	studying using a candle for you not to burn books or yourself. It also need to know the importance of light in the plants
L15	Yes, It is necessary to learn light in schools because light is the sources of energy as we all aware of. Learning light in schools also promote the understanding in many learners especially those who want to become doctors of eyes (sight) in future. Again it is the most everyday thing we see. So I really think that light should be learned in schools for better future of our generations.
L16	Yes, it is necessary because students (learners) they gain knowledge on how light works and it also helps students (learners) who to become optics as their future professional career to be having knowledge and skills on it and make it easier for them.
L17	Yes because light is very important in everyday life. It contribute also to some of our subjects not only in Physics we have to learn about light. In mathematics when we are doing reflection of a triangle in a mirror we need light to do so. To see everything that is happening around us, to do our school work and everything we want to do is just because of the presence of light.
L18	I think it is necessary to learn about light because everywhere you go there is light eg; sunlight, lamp light and so on. It is important to learn about light, the beam of light, the speed of light and all how it reflect an object
L19	Yes, I am sure its very necessary, because we learn alot , especially how the light travel, that light always travel light, And from that we also learn that if there was no light it couldnot be possible for us to see.
L20	It is necessary .There are many learners who want to go for dentists. Many have sight problem therefore their need to know their eye defects and how to correct them. Some will be drivers and they will use light (reflection) to see what is behind.
L21	From my side I think is good/necessary to learn about light at school, For us to know the danger and important of light
L22	Yes it is. Because we use light to see object around us during the day. We also need to learn how light travel and it's speed. We use light to check our apprerance in mirror.

Question 2: How do you feel during the lessons on the topic light? Explain your answer.

L1	I feel proud because I want to know how to use light and how to control it.
L2	I feel real good and lesson is always enjoyable. I learned the image formed by the plane mirror
L3	I feel boring because light
L4	Am always feeling proud as the things that we learn in this topic of light are those that we use at home or in the school ground. Things like mirrors we use them in dressing rooms, car drivers also use this when they are driving their cars.
L5	I feel grateful, because in this lessons of the topic of light, I got to understand how light travel in a straight line to reach the place where is needed. This lesson is always interesting, because I understand how light is formed
L6	During this topic of light I feel very happy because I learned more about light and its importance to different things especially to living things.
L7	I feels good, because this topic of light its much practicable and I like doing this and this. It makes me feel good because anyway anyhow we learn how to work with bulbs and how to connect them. I feels good as the lesson does not bring bored because this topic requires more attention. This topic of light impresses as it assist me on how to fix broken light instruments
L8	I feel good because our teacher like to teach us how light can work and how light can travel in a vaccum.
L9	I feel good because life is involved in everyday life. I learn about things or topic that I did not know before. Sometimes helps us in many things, even to know how light affect people if its bright.
L10	I am always felt much comfortably during lessons; because the teacher explains vey good and it always easy for me to cope and follow carefully because the things which are being explained by the teacher is just 100% correct as we does at home. I always felt good and the lessons seems like too short than others.

L11	I feel more enjoyable because from that time I know and gain some information about light like how much it can travel in a vacuum and through other medium. I also gain knowledges like how lightning and fantostoms are related to each other by light and sound on which states that how you see lighting first before the fanterstoms.
L12	I use to feel interesting because it helps me to know about eclipses, the two types or it , the sun and the moon eclipse and also about the transmission and absorption of light and the reflection of light in nature which is mostly concern of the formation of rainbow, internal reflection reflection and the glass prism and this things are the one making feel interesting.
L13	I feel different some times good and some times bad because some lessons where really nice expcialy prism. The light waves was't really explained and I did know what it is.
L14	I use to be happy because we learn more things about light e.g how the light refract and laser light. I always learning new thing about light and source of light e.g light refract that are use by people who work at road so that they can not be bumped by cars
L15	The lessons tend to be so much interested on this topic of light because more clear examples of light I am familiar with them. They tend to be more interested again because light is something we all know well and know where it comes from. I also feel happy about this topic because all around us, are things which can give off light, not only the naturals things but also the man-made are playing the role. Thats why I feel so much happy about the topic of light.
L16	I feel interesting because my dream is to become an optician, so I find the lessons interesting because I'm gaining knowledge about future career.
L17	I feel excited and impressed because I do learn things that I mostly know aready . I like leraning about things that lis around me and mostly used in everyday life like switching on a bulb to give light energy so that we can see when its dark . If there is no light we cannot see. To read about light I have to use my eyes to see the letters and this is what I am being tought, so thats why light is important and enjoyable.
L18	I felt good because when I am learning about light it feels good that each and everyday am using light and as it is applies in class it goes easy. When they strike boundary, so

	too are light waves. If the surface of the boundary is very shiny, as in a mirror, almost all the incident light is reflected.
L19	I feel so angry since until now I cannot be able to draw the refraction light by triangle and by a plane mirrors. And the formation of solar eclipse us not easily to identify
L20	As I want to know more I pay attention. Light is a easier topic in physics. Reflection is more on what we use at home e.g Touch, mirrors. We observ how to shadow is formed, mirages are formed, spectrum
L21	Very interesting hence we are learning things we see and do in our every day life at home
L22	I feel proud Because in this topic I learned more about light and it's use in realty. I also learn where light is been produced (The source of light)

Question 3: Which sub-topic(s) under the topic light do you enjoy most? and why?

L1	Wave because I gain more knowledge how waves are formed and sometime how it danger to the people e,g ocean wave and also ultraviolet light is necessary because it treating skin problem and used in washing powder.
L2	Reflection of light under this topic I learned that light reflected back when it hit object. I have learned that light travel in straight line and travel slow than sound
L3	Sources of light such as sun, electric bulb and candle. The uses of light such as to make someone to see well during night. Formation of shadows
L4	Refraction of light, Here we have to learn this inorder to know the optical density of materials through which light can travel (such as glass) to determine the speed at which light travels in the medium.
L5	Reflection, because it has many advantages living organisms, the light that is send back enable the vehicle driver to see what is behind them and in mirror for dressing.
L6	Reflection of light, I use to enjoy this topic because it use to supose me , especially the refraction of light in a mirror because the objects use to look like the original one.

L7	
L8	Reflection of light because we learnt the image in a plane mirror where there is many things that show the image is upright and laterally inverted.
L9	Speed of light, It help me to understand that a little bit about how light travels in short distance in long distance, about how it be deduced when it travels help me me to understand how fast light travels.
L10	Reflection of light-I really enjoy this topic because it has only to do with angle of incidence and many examples are our uses of every day such as ;combing the hairs with plastics com and taking jersey during winter
L11	-Eclipse of the sun and moon because we learn how sun reflect its light and how moon reflect its light pass through so that it may reach the ground.
L12	Eclipse is the one + enjoy most because it make me know about the two types of it e.g sun eclipse which happen when the moon is between the sun and the earth and also the moon (lunar) eclipse this the only topic.
L13	Speed of light, Because I really didn't know that light is faster than sound
L14	Refraction of light because I learned how the light refract and how it moves. Light is reflected from a far away object, and refracted into your eyes
L15	Illuminated and Luminous object. I do really enjoy both the sub topic because I am very much aware that Luminous object give off their own light while the Illuminated objects do not give their own light. A good examples to those gives light is the sun while to those do not give light is a moon.
L16	Reflection of light and Eclipse, basic concepts of light because I learned some those topics at home before
L17	Using lenses to improve sight. Because nowadays most people have sight problems and I wonder how spectacles make people to see better. I enjoy learning about this sub-topic because maybe I might be one of this people one day. I use to be serious and listen attentively when learning about this topic.

L18	Reflection because it act as a miracle that light is reflected through different objects when light is reflected from the image the distance and size is the same as the object.
L19	I mostly enjoy the formation of shadow, since I realy enjoy how the shadow is formed, and the light always travel in straight line
L20	Reflection by mirrors: We use mirrors in dressing it was not difficult to understand it.
L21	Reflection of light Because this property of light I use to do it at home and I don't use to find any difficulties.
L22	Refraction of light. I learn more on how to look at object which is under water.

Question 4: Which sub-topic (s) under the topic light do you find challenging? and why?

L1	The electromagnetic spectrum. Because I do nt now how to use the spectrum and how to increase and decreasing wave length.
L2	-how rainbow forms. I have seen this topic as challenging to me because the rainbow form 7 colour i.E red, orange, yellow, green, blue, indigo and violet which make me confusing. The ray coming out of prism show different colours from red to indigo
L3	The speed of light i find it more cha
L4	Mirages This sub-topic challenges me because I dont do understand it well because even if am home and try to discover what I tought it's of always difficult for me to get my analysis or conclusion.
L5	Short and long sight because these two sight can be drawn in many different way and some they make me confuse, because they look similar, but they are not.
L6	
L7	I have found nothing , every sub-topic was understandable thats why this topic its sensible. I found nothing challenging because all the sub-topic were explained clearly.
L8	Reflection in everyday life because light from glasses can cause accident if the light falls on a driver in a vehicle.

L9	How to calculate light energy in the bulb or in the electroscope
L10	Refraction- This topic is challenging because it says or it means that is the bending of light whenever light is passed from one medium to another . It also cause the speed of light ray to change.
L11	Reflection and refraction of light –t might be challenging like their explanation, how they travels and reflect and refract or light through an objects.
L12	Reflection by mirror is the topic I find more challenging because it's very complicated and got many sub-topic mostly the characteristics of an optical image formed by a plane mirror.
L13	Reflection of light on irregular substances because the rays don't go the same direction and I really don't know why this hapen
L14	Laser light because I don't understand it and it use atoms or molecules of a crystal, such as ruby garnet or a gas , liquid or other substance which is tough to me
L15	The sub topic of Eclipse. This, I really find it challenging because here the confusion comes in. It is a big challenge to me on the identification and describing the two types of eclipses. Those mentioned points are the one come with confusion and challenges.
L16	Transmission and absorption light and mirages because I never learned about this chapter at home (before) so I find them confusing sometimes especially on how light travels.
L17	Dispersion. It seems to be incredible just looking through a triangular prism and in a presence of white light you see different colours. I do ask myself where those colours come from because a prism does not have colours, it s colourless.
L18	Refraction, because I don't know how will light refract through a thick glass but it does not pass through the wall.
L19	Rays and beam, I had found it very challenging , because I failed to identify the difference between diverging and converging lens
L20	Refraction=The bending of light when heat the object. It is more confusing

L21	Refraction of light Because when ever we are drawing we have to obey some rules/laws which I find difficult some times
L22	Dispersion of light. Because am always stragling with identifying of colours.

Question 5: Give any examples of properties of light that you learned at home (if there is any).

L1	Light is a source of sound
L2	Light travel in straight line. Light is only pass through transparent object and Opaque object
L3	Light form shadow when blocked. Reflection and Refraction of light
L4	Things like reflection in a mirror as the distance of the object behind the mirror appears the same as the distance of the object infront of the mirror.
L5	I learn that light travels in a straight line for it to reach different places and where is needed.
L6	Light can travel in straight lines. Light can travel faster. Light can make something to make a shadow
L7	
L8	Plane mirrors Light bulb Frames from a candle or fire
L9	Solar light energy
L10	Opaque: A wood does not allow light to pass through it , therefore it absorbs a lot of light. Transparent: A glass usually allows light to pass through it .

	Translucent: A plastic can allow some of light to pass through it but absorbs some of light too.
L11	Nothing
L12	None
L13	-Lightning is seen 1 st and the thunder is heard after -Watching a person far from me chopping wood and I can see the action he is doing and hear the sound late
L14	Light travels in a straight line
L15	There It is, Light travel in a straight line only and when it travels it form shadow. As the light cannot bend around objects, when it blocked by an object by an Opaque in its way the shadow will be formed on the side of the object. Thats all the examples on properties of light.
L16	# Luminous objects # Illuminated objects #Eclipses
L17	Light is a source of energy, example lightning a candle and switching on a bulb it gives light energy. Light is gained from different sources like burning fire wood that is mostly used in rural areas when the night comes.
L18	-Light travels in a straight line -Light travels almost at the same speed -Light is the only wave can travel in avacuum.
L19	Plane mirrors-mirrors also translate light that you can see through #MSC
L20	1. Convergent rays: =light travels in straight lines. 2. Divergent rays: move away from each other e,g Touch

	2. Parallel rays: Of light stay the same distance from each other
L21	Reflection of light: Using a mirror
L22	Light travel in a straight line Light does not pass through the object except t if it is a transparent

Question 6: Would you like to take optics (the study of light) as your future professional career after grade 12 or not? Explain your answer.

L1	Yes because light is used to see clearly like when some people have eyes problem and went to the hospital to received glasses to see well even though the object are far apart.
L2	Yes I would like to take optics as my future professional career because still want to learn how light how travel in a vaccum space
L3	I can dn't think so because I have no career up to know but any way if I get to understand more it might become my future professional career
L4	No I don't want Because even if I want to study this topic, I want be easy because mathematics is the main obstacle in my studies even if I was born as a star in physic.
L5	Yes , because through optics, technology I want to know how the lense is used to form an image of an object for magnification in eye glasses used in spectacles optics are used in triangular prism to form the spectrum of colours.
L6	No I will not because I do not have more ideas and experiences about light
L7	Yes, I would like to follow it, *This is because I 'm good in physical sciences and in wording with light *I want to go help people who are suffering from blindness and help them glasses. *I would like to follow it because I know it might be a good field
L8	Yes because I want to know more about light How it's work and what is the benefit of light and challenge of light.

L9	No, because it is has many different topic which take time for some one to understand especially reflection and movement of light wave.
L10	Yes, I would like too; because I will need more information which I would use in my career I will take in my future. And it will not cost me a lot of time to succeed/sacrify my career
L11	Due to many experience that I gain on that topic of light I would like to take on optics on that either to be a teacher so that I might be able to taught that topic or to be a nice to learn and become a profess on that like to know the person lenses and sight on the years come after complete grade 12
L12	Yes, because I would like to be more concern on the eye patient and I would like to be their doctor for them. It will even help me to share with them on long-sightedness mostly those who cannot adjust objects that are short sightedness, those that cannot adjust objects that are far from the eye.
L13	Yes because I want to werk with eyes in this topic is where we talk about how eyes operate
L14	No, because I already choose my career that i like.
L15	Yes of course I would like to take the optics as my future professional career after grade 12 because I would like to become an doctor for eyes thus require the study of light. Working with light is the best way to correct them. To see whether a person got a long-sightedness or a short sightedness. I therefore would seriously like to take this my future professional career.
L16	Yes, because I learned and gain knowledge on how to correct defects of light (eyes defects) from this chapter and its my dream career so by having lessons on light it encourages me more to become an Option.
L17	Yes, because I want to be a doctor and dealing with people that long sighted (they see things that are far from them better that are near to them) some are short sighted. Some people have converging lenses and some have diverging lenses withought knowing it. I think each and every person need to know their eyes function and in most cases many

	don't know even the reason why they put on spectacles. So I want them to know they pun on spectacles.
L18	I don't want to study optics, because it deals with inside the eyes and requires Biology and physics and am sure that I ain't familiar with the two. And to be honest I can't out someones flesh.
L19	No, because I already find it challenging in grade 10, I cannot differentiate between properties of light e.g Transparent and opaque. And the transmission of light is also difficult to detect
L20	=Light is more observation. =It can cause eye catalacts Reflection of light from a wet road can be dangerous to a driver
L21	Yes as I would like to be a doctor I will need light everyday to carry all the light work propery
L22	Of course yes I want to learn more on how light is being produced in the electrical bulb and why light shine if it hits the shiny object and why it does not pass through solid object except the transparent one

Question 7: Is there anything you would like to share with me regarding me the topic on light?

L1	Yes, I just want you to know that light is not needed to be spoiled it needed to be use well for our country to be in good develop
L2	Yes There is the topic converging and diverging lenses to improve sight
L3	Nothing unless to emphasis more on the speed of light And also to reflection and Reflaction

L4	Something that,we want to share with you is We need that we can learn how doctors do when they want to observe or to see what is inside a human body using light so that we can understand better. Thank you.
L5	Nothing to share in this topic
L6	None
L7	Yes, I just wanna say that let keep this topic of light longer so that youth could gain knowledge on how to work with light. Lets keep it so that upcoming children will also be familiar to it and everywhere nationally light is used
L8	-Formation of shadow that light travel in a straight lines -light travels from a luminous object -if the light source is very large
L9	Ye, as you are a teacher you suppose to only focus on that chapter and you make sure that learner are understand. Also to contact those nurses and doctor that clealing with sight deficiency
L10	Modern society depends on electricity for communication and as the source of light. I addition, we need knowledge of light to understand its originated. This help us to understand chemistry and natural phenomena such as lightning.
L11	Yes I would like to share with you on reflection by mirror on how should the light get how the mirror and reflect its light back and also in a wall (building) and how is the camera function.
L12	Yes I want to share with you about how the human eye functions when light is involved. I also want to share with you on eye defects and how to correct them
L13	Does thunder really happen before the lightning #MSC
L14	Nothing much but light is good and very important in our lives.

L15	Yes, Its just to conclude that light got use in reality not only as the source of energy but an important thing in our lives which provide good benefits in our future. So us the generation are taking part in the study of light to learn the important facts about light. Just to share my information to you.
L16	Yes, On mirrages topic because I find it challenging to me.
L17	No
L18	I don't want have much to say but as this topic of light was a good choice as good topic to do the research. I got nothing as much to say all that I know you know.
L19	Yes, about eclipse of the moon (lunar eclipse) -the moon moves into the shadow cast by the earth and disappears from the night sky an eclipse occur when the moon is a form of shadow
L20	Sunlight is often called white light since it is a combination of all the visible colors. When passed through a transparent medium is known as dispersion of colour
L21	Yes, the light in electricity
L22	Yes, On how light is reflected by the mirror

APPENDIX G: Collated data from pre-test

Collated data from pre-test

Question 1

L1	B), (Certain). White colour is more clear visible in darkness. (Almost certain).
L2	B), (A totally-guessed answer). Because it is dark and the dark colour and blue cannot be seen well as they relate to the dark room. (Almost a guess).
L3	B), (Certain). Because white reflect light. (Certain).
L4	B), (Almost certain). Because the white paper can be seen through dark colour and the black & blue paper can not be seen as it is same colour as dark one. (Almost certain).

L5	B), (Certain). I am sure because the white colour is good in reflecting the light. (Certain).
L6	B), (Almost a guess). Because white colour reflect light. (Almost a guess).
L7	B), (Certain). Because a white paper has a sharp look and can be easily seen in the darkness. (Certain).
L8	B), (Almost certain). Because white coloured have a certain of light in dark or black place. White can be easily seen because it's colour is strong apearence than order colours.
L9	A), (Almost a guess). IS an Illuminated object. (Almost a guess).
L10	B), (Almost certain). White because is a good reflector it can reflect any source of light come o it while black is good absorber light will get in but not get out. (Certain).
L11	B), (Almost a guess). Because the white colour can absorb light easily than others. Therefore it can be easily seen. (Almost certain).
L12	B), (Certain). Because the white colour can be seen during the night or when kept on an dark room. (Certain).
L13	B), (Almost certain). Because the white paper can not change colour like the other one, remain the same. (Almost certain).
L14	B), (Certain). Is because white colour is more dectetable even it is in a dark place than blue and black. On the other hand even is dark there will a little light and when that little light hit on the white paper it make the light to reflect back in to your eyes. (Almost certain).
L15	B), (Certain). White paper is reflectable and it can be seen in dark while black is absorbable it cannot seen in dark because it is also dark. (Almost certain).
L16	B), (Certain). Because a white colour is the one which contain white colour it can be easily seen unlike blue and black colour. It can reflect light back. (Almost certain).
L17	B), (Almost certain). Because white object can easily reflect the light or is good absorber than other colours. (Almost certain).

L18	D), (Certain). None of the paper will be seen because dark is not transparent everything placed in a dark room even the table that they place this colour papers will not be seen, so everything is invisible. (Almost certain).
L19	B), (Almost certain). Because white colour reflect light and do not absorb the dark in the place. (Almost a guess).
L20	B), (Certain). Because white is visible in the night. (Certain).
L21	B), (Almost certain). Because white colour can be seen clearly on dark surface. (Almost certain).
L22	B), (Certain). Am sure enough because I have notice this many times during the night when you meet someone wearing the white clothes, it is easily to be see this person and this is the same as the anser in 1.1 B. (Almost certain).

Question 2

L1	A), (Certain). Actually reflection, because it is generating inverted image of the zebras it is well known that it send back image. (Almost guess).
L2	A), (Almost certain). Because before one mouth of the zebras reach water to drink the body shadow will seen in water before it drank. (Almost certain).
L3	C), (Almost certain). Because there are lenses involved to come up with this image. (Certain).
L4	B), (Almost certain). Because Refraction is the bending of light, which means as light hit on an object it bends. (Almost certain).
L5	B), (Certain).
L6	B), (Almost certain). Refraction is the bending of light where by the(Certain).
L7	A), (Almost certain). Because reflection is when a object is reflected through light. (Almost certain).

L8	A), (Certain) . Water acts as a mirror, when you found it clean and shine are on a dark soil or anything hold it you can easily identify your self in water. (Certain) .
L9	B), (Certain) . The image of the zebra is reflected. (Certain) .
L10	B), (Certain) . Water as a mirror to reflect the image of the zebra looking upset down. (Almost guess) .
L11	B), (Certain) . Because light through water medium can refract whereby the image could be identified with some bending. (A totally-guessed reason) .
L12	B), (Almost certain) . I think it will refract because the zebra can reflect it's-self into the water. (A totally-guessed reason) .
L13	B), (Almost certain) . Because it look like a mirror. (Almost certain) .
L14	D), (Certain) . Is because diffraction use to do with image in water and the image looks upside down. (Almost certain) .
L15	A), (Certain) . the image of the zebra is reflected in the lake (water) and reflection is the sending back of the light or image. (Certain) .
L16	A, (Certain) . Zebra can reflect light from the water because water is a transparent and it is a shining object light can be reflected back to the water. (Almost certain) .
L17	B), (Almost certain) . Because the zebra reflect it's shadow through the lake due to its colour. (Almost certain) .
L18	A), (Certain) . Its reflection because the up part of the image becomes the down part and the down part of the image becomes the up part. (Almost certain) .
L19	A), (Almost certain) . because in reflection is where an image is formed in a mirror or any shiny object. (Almost certain) .
L20	B), (Almost guess) .
L21	--
L22	C), (Almost certain) .

Question 3: (3.1)

L1	C), (Almost certain). Needed to be parallel to a mirror in order to provide light equal to both sides either to you or ether to the mirror. (A totally-guessed reason).
L2	A), (Certain). Because if the flashlight is aimed at his chin he cannot able to see his chin in the mirror clearly because he is in darkened barroom and the light only flash at her chin not on the mirror. (A totally-guessed reason).
L3	B), (Certain). Because the light should be on his chin for him to see himself in the mirror. (Certain).
L4	B), (Certain). Because flashing will make him to be seen in the mirror. (Almost guess).
L5	B), (Certain). I m very sure because the flashlight should be aimed at his chin so that his chin will reflect light into the mirror for him to see his image in the mirror. (Almost certain).
L6	A), (A totally-guessed answer).Because the mirror has to reflect the light from the flashlight. (A totally-guessed reason).
L7	B), (A totally-guessed answer).because you place a flashlight at your chin it will clearly make the mosquito bite visible if you place on the plane mirror it will be hard for you to identify the bite. (Almost certain).
L8	B), (Almost certain). because Mirror work with right, If you want to see yourself in mirror during night, you should provided with right, mirror refrect everything even the darkness of the night is only that you can control it dark is very larger. (Almost guess).
L9	B), (Certain). For him to see clearly he has to aimed it on his chin. (Certain).
L10	B), (Certain). He must flashlight to his chin so that light rays reflected from chin to the mirror because if he flash light to the mirror he will not see chin because the light reflected directly in his eyes. (Almost certain).
L11	B), (Certain). Because when flashlight the plane mirror , the light will be reflected back into his eyes and. therefore he could not able to see him self. (Almost certain).

L12	B), (Certain) . Flashlight should be aimed at his chin, just for her to see clearly the bite and can be only seen well by the answer I choosen on 3.1. (Certain) .
L13	--
L14	C), (Certain) . The flashlight should be parallel to the mirror, so that when light hit chin he could be able to see him-self but if he put the flashlight at his chin when light hit the mirror it has to reflected back to his chin he can not see his chin. (Almost certain) .
L15	A), (Almost guess) .The flashlight should be aimed at the plane mirror for the mirror to reflect light to the chin. (Almost guess) .
L16	C), (Almost guess) .The mirror must be placed parallel to the flashlight to reflect light from the mirror to the chin of Angula inorder to see himself in the mirror. (A totally-guessed reason) .
L17	B), (Certain) . Because he need the flashlight on his chin for her to see, because the mirror can reflect light to his face. (Almost certain) .
L18	B), (Certain) . For him to be able to see well the chin because it light so it's clearly visible. (Almost certain) .
L19	B), (Certain) . Because when you flash on the mirror you will only see the darkness and when you flashlight on your chin you will see your self clearly in the mirror because the mirror reflect light. (Almost certain) .
L20	B), (Almost certain) . ---
L21	B), (Certain) . Because you cannot point a flashlight on a mirror and expect to see your self in the mirror because the light only travels straight at the mirror your face will be in the dark. (Certain) .
L22	E), (A totally-guessed answer) . I have never discover this that is why am referring to the answer in E, I totally gase this answer. (A totally-guessed reason) .

Question 3: (3.5)

L1	D), (Certain) . The flashlight need to be parallel to the mirror, in order to give off light directly to the side where you are and where there is a mirror. Allowing you to see yourself very well. (Certain) .
L2	B), (Almost certain) . When the light reflect back to a mirror it reflect back to a chin when a person look on it. (Almost certain) .
L3	A), (Certain) . Because the light that the flashlight applied to his chin will be sand back with hi image to the mirror and mirror will reflect the image into his eyes. (Certain) .
L4	A), (Almost certain) . If you happen to take a torch in the midnight and mirror you normaly use to face the torch so that you can able to see your self in a mirror. (Almost certain) .
L5	A), (Certain) . It should be done as diagram A so that you can see well your image in the mirror. (Certain) .
L6	A), (Certain) . Because the light from the lightflash is reflected by the mirror to the chin. (Certain) .
L7	A), (Almost certain) . Because light is reflected through the mirror. (Almost certain) .
L8	A), (Certain) . Because the mirror work with light. Mirror reflect everything , if light appear on something being reflected by a mirror you can easily identifiyed. (Certain) .
L9	A), (Certain) the flash has to be parallel to the Chin. (Certain) .
L10	A), (Certain) . The flashlight on the .Chin reflect to the mirror and mirror reflect optimim rays to the eyes. (Certain) .
L11	A), (Certain) . The torch flashlight into his chin , whereby light can not be reflected. He coulds see well himself. (Certain) .
L12	A), (Certain) . The flashlight has to aimed on the chin, so that he later check himself into the mirror but the mirror should give the answer of the bite, wether he is bitten hadly or not. (Certain) .
L13	A), (Almost certain) . Because light travel in a straight line and. (Almost certain) .

L14	A), (Almost certain) . Because I can see that as light hit on Angula's chin the light has reflected from the face to the mirror and he could really see his chin very well. (Almost certain) .
L15	C), (Almost a guess) .the light must be from the mirror to a chin for Angula to see his chin and if the flashlight aimed on the chin the chin does not reflect the light. (Almost a guess) .
L16	A), (-) . You must face your mirror to the face if you face the mirror to the light torch you won't be able to see yourself. Light reflected from the mirror to the face. (-) .
L17	A), (Certain) . Because light need to be on the face for it to be reflected into the mirror. (Certain) .
L18	A), (Certain) .Diagram in A represent totally the way the flashlight should be aimed at his chin for him to be able to see. (Certain) .
L19	A), (Certain) .Because the flashlight is on the chin and not on the mirror because the mirror reflect light. (Certain) .
L20	A), (Almost a guess) .----
L21	A), (Certain) .because the flashlight is pointing on the chin. (Certain) .
L22	A), (Certain) .In the flashlight is facing at his chin where by the flashlight is reflecting the his chin to see where the mosquito bite through the mirror. (Certain) .

Question 4

L1	B), (Certain) .The location of the images seen by both students are reflected to the other side. (Almost a guess) .
L2	A), (Almost a guess) .They are at the same side of the table with the same distance between them end to the mirror. (Almost certain) .
L3	B), (Certain) . Because the pencil is not teaching the mirror. (Certain) .

L4	A), (Almost a guess) .Because the pencil is between both students & everyone can able to see. (Almost a guess) .
L5	C), (Almost a guess) .-----
L6	A), (Certain) .Because if you are looking at yourself in the mirror, your left eye is on yo always on your left hand side and your light eye is always on your light hand side. (Certain) .
L7	A), (A totally-guessed answer) .because the pencil is in the middle and the distance is the same between two students. (Almost certain) .
L8	A), (Almost a guess) .Mirror make right to become left in a mirror Is only that you and the image in the mirror you are not faced at the same direction, so the appearance of right side it will seen appearing on left side. (Certain) .
L9	A), (Almost a guess) .They is all (Tangi) Nangula sitting on the same side. (Almost a guess) .
L10	B), (Almost a guess) . It's because they are not at the same place and they seen it from different direction. (A totally-guessed reason) .
L11	A), (Almost certain) .Because they are at the same distance from their sit to the object which to a pencil and a light same with is a mirror. (Almost a guess) .
L12	B), (A totally-guessed answer) . I think Tangi (boy) he will just see the location of the image on the right side of the seen by Nangula just because the boy is on the left side so he will see the object on the right side. (Almost certain) .
L13	A), (Almost certain) .Because these two student are sitting on the same direction. (Almost certain) .
L14	C), (Certain) .Because image on the mirror the right seems to be left that is why Tangi has saw them on left side. (Almost certain) .
L15	A), (A totally-guessed answer) . The locations of the image won't change because the object (pencil) did not move. (A totally-guessed reason) .

L16	C, (Almost a guess) .The location of the pencil, boy and girl are all seen in the mirror although their position is changed the is on between the boy and the girl while the boy stay at left hand side and the boy at a right hand side. (Almost certain) .
L17	B), (Almost a guess) . Because it is so difficult for me to see well their normally sitting. (Almost a guess) .
L18	-----
L19	A), (A totally-guessed answer) . Because the image will be seen the same because they did not change their position they where just on the same. (Almost a guess) .
L20	A, (A totally-guessed answer) . -----
L21	A), (Almost a guess) .They are both facing the mirror which is inbetween them thew the pencil is also located between them on the table they can see pencil at the same location. (Almost certain) .
L22	A), (Certain) .-----

Question 5

L1	D), (Almost a guess) .Totally disagreed because the pencil moved further away from the mirror it cannot be seen because it is very far from the mirror. (A totally-guessed reason) .
L2	A), (Certain) .Only the boy can see image because he is not on beyond the perpendicular to the mirror while the girl is totally beyond and next to the pencil. (A totally-guessed reason) .
L3	A), (Certain) . Because the angle of reflection is not 90° (Certain) .
L4	B), (Almost certain) . Because the girl is at aside where the pencil is. (Almost certain) .
L5	E), (Almost a guess) . It is non of the above because each one can only the image of her friend. The boy can see the image of the girl and the girl can see the image of the boy. (Almost certain) .

L6	E), (A totally-guessed answer).I think it is because they go beyond the region of perpendicular to the mirror. (A totally-guessed reason).
L7	A), (Almost certain).because a boy is parallel to the image so he will see it clearly. (Almost certain).
L8	B), (A totally-guessed answer). Because---
L9	A), (Almost certain). Because he is on the right at the edge of the mirror and the pencil also which means he can see it. (Almost a guess).
L10	A), (Almost a guess). It's because a boy seen it reflected from the table. (A totally-guessed reason).
L11	A), (Certain). Because the boy is perpendicular to the pencil. Therefore he can see the image formed while the girl is opposite to the pencil whereby she could not see the image at all. (Almost certain).
L12	A), (Almost certain). Because the boy is on the right of the region, so the boy can be able to see the pencil while the gal cannot see the pencil because it is on the same position as her (gal). (Certain).
L13	B), (Almost a guess).Because the girl is the one who move on the right side and the pencil also moved on the right side. (Almost certain).
L14	B), (Almost certain). Because the image of the pencil has to be at the other corner where the boy is and the boy can no be able to see the image. (Almost certain).
L15	A), (Certain). Only the boy can see the image because the pencil is on the edge of the mirror and the boy is perpendicular to the mirror. (Almost a guess).
L16	A), (A totally-guessed answer). A boy can see the image of the pen because it lie perpendicular to the mirror a girl cannot see because they lie in the same line with the pen. (Almost a guess).
L17	B), (A totally-guessed answer). I think only girl because the is girl is the one sitting closely to the plane mirror can see the pencil best than the boy. (Almost a guess).
L18	C), (Certain). Because both are parallel to the image. (Almost a guess).

L19	A), (Certain). Because the boy will be able to see image because he is far a distance from the edge, but the girl will not because is on the same level with the age. (Certain).
L20	A), (A totally-guessed answer). -----
L21	B), (Almost certain). They can both see the mirror so they all see the image. (Almost certain).
L22	C),-----

Question 6

L1	A), (Certain). It will move up because the light makes the image of the pencil to move up. (A totally-guessed answer).
L2	B), (Almost certain). Because the light may make the image to be seen move down. (Almost a guess).
L3	C), (Certain). It is only the lamp that is moved but not the table or the mirror or even the pencil it self. (Certain).
L4	B), (Almost a guess). If you move the lamp up, then the pencil will move down.
L5	B), (Certain). It will move down because the source of light (bulb) move upwards. (Almost certain).
L6	B), (Almost certain). Because the higher the light shorter the image can be seen is the right spread over an angle to the image. (Almost certain).
L7	B), (A totally-guessed answer). Because the light and the object are inverse the highes the light the lower the object. (A totally-guessed reason).
L8	C), (Almost a guess). Mirror only work with light to make it easiy for you to identify the object but is not the light locate the position of the object in a mirror. (Almost certain).
L9	B), (Almost a guess). As the lamp is raised the image will move down. (Almost a guess).

L10	B, (A totally-guessed answer) . It is because source of light go further. (A totally-guessed reason) .
L11	C, (Almost a guess) . Because. (Almost a guess) .
L12	B), (Almost certain) .The pencil will be seen by the observer as it will move down because the lamp is raised a little higher from the object(pencil). (Almost certain) .
L13	B), (Almost certain) . Because the light move up the image of the pencil move down. (Almost certain) .
L14	B), (Certain) . Because use to same distance and position as the object. (Almost certain) .
L15	B), (A totally-guessed answer) . As the illuminated raise up and the observer is horizontal pallarel to the mirror the object will move down because the light is travelled straight. (Almost a guess) .
L16	D), (A totally-guessed answer) . -----
L17	B), (Almost certain) .Because the mirror has move higher so the image can bee down in order to be seen. (Almost certain) .
L18	A), (Certain) . Because the lamp has been also raised. (Almost certain) .
L19	C), (Almost a guess) . Because the lamp is higher than the pencil so the it will stay in the same place. (Almost a guess) .
L20	B), (Certain) .-----
L21	C), (Certain) . Only the lamp which move not the mirror or neither the pencil. (Certain) .
L22	-----

Question 7

L1	A, (Certain) . The image will become longer because the more you are raising highly the lamp the more the image is becoming longer. (Almost a guess) .
L2	C, (Almost a guess) . The image shown by a lamp will be seen as it is. (Almost certain) .

L3,	C, (Certain) . Because only the lamp that is not the pencil is made longer. (Certain) .
L4	C, (Almost certain) . Because nothing will make it to become longer nor neither shorter. (Almost certain) .
L5	B, (Certain) . The image will become shorter because the bulb move up. (A totally-guessed reason) .
L6	B, (Almost certain) . The higher the light spread the shorter the image. (Almost certain) .
L7	B, (A totally-guessed answer) . Because it is increasing in light it will decrease in distance. (A totally-guessed reason) .
L8	C, (Almost certain) . Nothing will be change in the mirror on the pencil as it's being observed. (Certain) .
L9	B, (Almost a guess) . The higher the lamp the shorter the height of the image will be
L10	B, If light is close the image will become large but if light move further the image become smaller. (Almost a guess) .
L11	B, (Certain) . Because the lamp move further upward the image formed will therefore move/decreasing in height because the light rays between the image and the source of light is longer. (Almost certain) .
L12	B, (Almost certain) . Because the lamp is raised a little higher, so the image will become shorter, just because the observer can see it shorter as the lamp is up higher little. (Almost certain) .
L13	C, (Almost certain) . Because No changed. (A totally-guessed reason) .
L14	A, (Almost a guess) . Because the light is much far. (Almost a guess) .
L15	C, (A totally-guessed answer) . the image only change when the distance between the object and the mirror is longer it will be shorter while if the distance between it is short the image wilkl be longer. (Almost a guess) .
L16	B, (Almost certain) . Because the lamp is raised higher up the image will become shorter because there is a short distance from the mirror and a source of light. (Almost certain) .

L17	C, (Certain) . Because light cannot change the shape of any object but it can only reflect it back. (Almost certain) .
L18	B, (Certain) .-----
L19	C, (Almost a guess) . Because the pencil is not in focus of the lamp so it will remain unchanged. (Almost a guess) .
L20	B, (Certain) . Because the lamp is raised up. (Almost a guess) .
L21	C, (Certain) . The pencil did not move only the lamp on which the pencil is on so the height of the pencil will not raise or become shorter. (Certain) .
L22	A, (Almost certain) .Because this the same as during the night when moon raised up your shadow is always longer than during the day. (Almost certain) .

Question 8

L1	B, (Almost certain) .The more you are moving it back further from the mirror, the image will become shorter because the distance is decrease. (Certain) .
L2	B, (Almost certain) . Because it is further from the mirror and it can not be seen well in the mirror. (Almost certain) .
L3	B, (Certain) . Because the far the object the shorter the image. (Certain) .
L4	B, (Almost certain) .Because if you increase a distant object away from a mirror it become larger. (Almost certain) .
L5	B, (A totally-guessed answer) . -----
L6	B, (Certain) . The closer the object to the mirror the larger the image, (Certain) .
L7	B, A totally-guessed answer) . because it will be unqual that as the object is moving away it will be small. (Almost certain) .

L8	B, (Almost certain) . The mirror is the only do it with the position of the object-if the object is far from the mirror it will also appear far, and small in the mirror. (Almost certain) .
L9	B, (Almost a guess) . The longer the distance, the shorter the image will be (Almost a guess) .
L10	B, (Almost certain) . If the image is close to the mirror it will look bigger but it move further if become smaller. (Almost a guess) .
L11	A, (Almost a guess) . Because the closer the pencil to the mirror. The image becomes shorter. As you move further the pencil away more area of the pencil will be seen in the image. (Almost a guess) .
L12	A, (Almost a guess) . Because the mirror is move away from the pencil which make to be longer and thinner in size. (A totally-guessed reason) .
L13	B, (Almost certain) . Because if the pencil far to the mirror it will always the height become shorter. (Almost certain) .
L14	A, (Almost certain) . Because as you increase the distance you also increase the light. (Almost a guess) .
L15	A, (A totally-guessed answer) . (The image change if the distance is increased. (Almost a guess)).
L16	A, (Almost a guess) . There is long distance from the mirror to the source of light. (Almost certain) .
L17	B, (Almost certain) . Because the shorter the light, the longer the image . The higher the light the shorter the image. (Almost certain) .
L18	B, (Certain) . -----
L19	A, (A totally-guessed answer) . Because the pencil is now on the focus on the light from the lamp the lamp so the image will become longer. (Almost a guess) .
L20	C, (A totally-guessed answer) .-----

L21	A, (Certain) . The image seen in the mirror will become longer as the pencil move further from the mirror. (Certain) .
L22	D, (A totally-guessed answer) . really don't know so am referring to the answer in D. (Certain) .

Question 9

L1	A, (Almost a guess) . It will refact from the mirror because the observer is still looking in the mirror even though the lamp stays fixed. Therefore the location of the image refret from the mirror. (Almost a guess) .
L2	A, (Certain) . Because they move further from the mirror. (Almost certain) .
L3	C, (---). Because the pencil did not move. (Almost certain) .
L4	A, (Almost a guess) . Because the person can be seen thoroughly. (Almost a guess) .
L5	C, (Almost certain) .-----
L6	C, (Almost a guess) . I think so because of the fact that the pencil does not change the location but it is the distance which has changed. (Almost a guess) .
L7	A, (A totally-guessed answer) . because it is a refraction that the observer moves a bit far from the mirror. (Almost certain) .
L8	C, (---). Nothing will be changed in the mirror on the pencil as it it's being observed. (Certain) .
L9	B, (Almost a guess) .As you are far you will observe the image as it approaching the mirror. (Almost a guess) .
L10	C, (A totally-guessed answer) .-----
L11	-----
L12	A, (Certain) .Because the observer retreats from the mirror and the only option that can be observed. (Certain) .

L13	C, (Almost a guess) . Because the observer stay the same direction. (Almost a guess) .
L14	C, (Almost certain) .-----
L15	C, (A totally-guessed answer) . the location will not change because is not the object (pencil) which move only the observer and the longer the distance between the observer and the mirror the small the object. (Almost certain) .
L16	D, (A totally-guessed answer) . the object does not move a person is the only one that move. (A totally-guessed reason) .
L17	A, (Almost a guess) .Because I think the observer show a pencil in other / different direction. (Almost a guess) .
L18	C, (Certain) .Nothing is moving. (Certain) .
L19	B, (A totally-guessed answer) . Because the image will not be charged by the retreats of the person. (A totally-guessed reason) .
L20	C, (Almost certain) .Because only an observer who moved but not pencil or a lamp. (Almost certain) .
L21	A, (A totally-guessed answer) . The size of the pencil in the mirror will be seen smaller as the observer moves away from the lamp. (Certain) .
L22	-----

Question 10

L1	A, (Certain) . I agreed because object that are near the plane mirror are the only ones able to form images. (Almost a guess) .
L2	D, (Almost a guess) . It is infront of a plane mirror. (Almost certain) .
L3	B, (Certain) .The length between the mirror and the object should be the same to the length between the image and the mirror. (Certain) .

L4	B, (Almost certain) .Because the plane mirror left becomes right and right becomes left. (Almost certain) .
L5	B, (Certain) . the position B is the correct because the distance from the plane mirror towards them is the same and object's right become the left on the image. (Certain) .
L6	B, (Almost certain) . Because image formed on plane mirror, right become left and vice-versa. (Almost certain) .
L7	B, (Almost certain) .because the distance between B as the object is equal. (Almost certain) .
L8	B, (Certain) .The mirror form the image according to the object being observed. It will be as the object to how far , up or closer is the object, It will be the same appearance. (Almost a guess) .
L9	C, (Certain) .It will just remain at its position. (Certain) .
L10	B, (Certain) . Angle of the actual image is equal to the angle of reflection and distance is also equal. (Certain) .
L11	C, (Certain) .Because light is being reflected by the mirror. Therefore C is the reflected rays. (Almost certain) .
L12	D, B (Almost certain) .because D is not closer to the mirror. (A totally-guessed reason) .
L13	B, (Almost certain) .Because the object cannot change it remain the same. (Almost a guess) .
L14	B, (Certain) .image use to be same distance as the object in the mirror. (Certain) .
L15	C, (Almost a guess) .-----
L16	D, (A totally-guessed answer) . it changed the position stay downward and face to the left side of the mirror. (Almost a guess) .
L17	C, (Certain) . Because the object apper the same as its occur on the mirror. (Almost certain) .
L18	A, (A totally-guessed answer) .-----

L19	C, (Certain) .Because the image stays the same distance as the object from the mirror. (Certain) .
L20	B, (Certain) .Because the distance of an object to a plane mirror is equal to the distance of an image to a plane mirror. (Certain) .
L21	D, (Almost a guess) .The object in D is parrall to the actual object. (Almost certain) .
L22	B, (Almost certain) .Because the distance of the object to the mirror is the same as the distance from the mirror to B. (Almost certain) .

Question 11

L1	A, (Certain) .I am saying wooden table, because wood is a poor conductor of heat as all know. (Almost a guess) .
L2	C, (Certain) .Because it has a lens which reflec t the light. (Almost certain) .
L3	C, (Certain) . Because the mirror is shiny. (Almost certain) .
L4	C, (Almost certain) . Mirror reflect light means it send back light. (Almost certain) .
L5	B, (Almost a guess) .It might be a silver spoon because it is shiny and shiny objects reflect light. (Certain) .
L6	D, (Almost a guess) .Because if there is light you can show some shadow. (Almost a guess) .
L7	C, (Almost certain) .because the mirror reflects light. (Almost certain) .
L8	C, (Certain) .
L9	B & C, (Certain) .Silver spoon it will reflects because is shiny are also the mirror. (Certain) .
L10	B, (Certain) .It 's because silver is bad absorber it is only reflect while a mirror reflect, (Almost certain) .

L11	C, (Certain) .Because a mirror is a source of light. Silver spoon can reflect but not like mirror. Wood table can not reflect at all. (Almost a guess) .
L12	C, (Certain) . Because the mirror is the object used when reflect the light ray. (Certain) .
L13	C, (Almost certain) .because the light can reflect on the plane mirror. (Almost a guess) .
L14	C, (Certain) .As we see our appearance in a mirror is because of the light which is reflected by the mirror. (Certain) .
L15	B, (Certain) .Silver is good reflector and it is a bad absorber and it is a bad emmitters. (Almost certain) .
L16	A, (Almost certain) .mirror is the only one which can reflect light back to the object and from an image. (Almost a guess) .
L17	C, (Certain) .This is cause by the parallel rays that heat the mirror so that it can reflected them back. (Certain) .
L18	A, (Certain) . Because wooden table would be a bad conductor of heat and so light is reflected. (Almost certain) .
L19	C, (Almost a guess) .Because in the other object It will form a shade so the mirror reflect light. (Almost certain) .
L20	C, (Certain) .Because it is shiny. (Certain) .
L21	C, (Certain) .The mirror can send back the light as it heats it it. (Almost certain) .
L22	C, (Almost certain) .Because we use mirrors in every day life as in dressing room to see our self in case this done because of reflection. (Almost certain) .

Question 12

L1	B, (Certain) .The angle of reflection is just equal to the angle of incident. (Certain) .
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L2	B, (Certain) . Because the angle of incidents equal to the angle of reflection. (A totally-guessed reason) .
L3	B, (Certain) .Because the angle of incoming rays should be the same as the angle of reflection rays. (Almost certain) .
L4	B, (Almost certain) . Because the angle of incidence is equal to the angle of reflection. (Almost certain) .
L5	B, (Certain) .It is 30 degrees because is must be equal to the angle of incidence. (Certain) .
L6	B, (Certain) .Because the angle of incidence is equal to the angle of reflaction. (Certain) .
L7	B, (Almost certain) .because anlges of reflection are always equal. (Almost certain) .
L8	D, (A totally-guessed answer) .-----
L9	B, (Certain) . Angle of reflection is equal to the angle of incidence. (Certain) .
L10	B, (Certain) .Angle of actual image is equal to the angle of reflection. (Certain) .
L11	B, (Certain) .Because the angle of incidence is equal to the angle of reflection always. (Certain) .
L12	B, (Certain) .Because the equal angel should be the same of the angle. (A totally-guessed reason) .
L13	B, (Almost certain) .Because the angle of incident is equal to the angle of reflection. (Almost certain) .
L14	B, (Certain) . Because the angle of incident layer is equal to the angle of reflection. (Certain) .
L15	B, (Almost certain) . because the angle of reflection is equal or equilibrium to each other. (Almost certain) .
L16	C, (Almost certain) .it lie 60° from the angle of relation to the angle reflection. (--) .

L17	B, (Certain) .Because angles on the incident rays and reflected rays are always equal. (Almost certain) .
L18	C, (Certain) .one complete angle is is 60 degree. (Almost a guess) .
L19	B, (Almost a guess) . Because is reflected 60 degrees. (Almost a guess) .
L20	B, (Certain) .-----
L21	B, (Certain) .Because the on the same angle. (Certain) .
L22	B, (Almost certain) .This is because the angle of incident is equal to the angle of reflection. (Almost certain) .

Question 13

L1	B, (Almost certain) .As the air travel from air into glass, yes its true speed changes because know light travel a shorter distance to hit the glass. (Almost certain) .
L2	A, (Almost a guess) .because light travel in a vaccum. (A totally-guessed reason) .
L3	D, (Certain) .Because refraction is the movement from air into different medias. (Certain) .
L4	D, (Almost certain) . Because light travels through glass it for different colours of a rainbow. (Almost certain) .
L5	B, (Certain) . it is dispersion because dispersion is the movement of air in different medium objects. (Almost certain) .
L6	B, (Almost certain) .Because the angle of incidence is equal to the angle of reflaction. (Almost certain) .
L7	D, (A totally-guessed answer) . because light travels in a straight line. (Almost certain) .
L8	D, (A totally-guessed answer) .-----
L9	B, (Certain) .When light travel into glass it make spectrum colours on the glass. (Certain) .

L10	A, (Almost certain) .It allows light to pass through freely. , (A totally-guessed reason) .
L11	D, (Certain) .Because light travels through a glass medium, light bends and slow down. Therefore object through a glass ca not be seen well. (Almost certain) .
L12	A, (A totally-guessed answer) . Because thats the effect caused when light travels from air into glass as its speed change. (A totally-guessed reason) .
L13	B, (Almost a guess) .Because air move into glass. (Almost a guess) .
L14	B, (Almost certain) .Because light travel fast in air but travel slow in solid object which are transparent. (Almost certain) .
L15	D, (Almost a guess) . because the light refracted in the glass and the direction of the light will change. (Certain) .
L16	A, (---). air is very ligher while glass is dense than air. (---).
L17	B, (Almost a guess) .Because it need dispersion light for the changes to take place. (Almost a guess) .
L18	-----
L19	D, (Almost a guess) . Because the glass will refract the light to form a light image. (Almost a guess) .
L20	B, (A totally-guessed answer) .-----
L21	A, (---). It has to do with the speed of light in different medium. (Almost certain) .
L22	B, (Almost certain) .As of the light will reflected back so the speed will change. (Almost certain) .

Question 14

L1	A, (certain) . The person have long sightedness as eyes defect and convex as the lens. Therefore this person may not see very well the objects that far. (Certain) .
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L2	B, (Almost certain) . Because the person only see the object that are far from her & his and form a concave lens. (Almost a guess) .
L3	C, (Certain) . Because the person can not see far. (Certain) .
L4	C, (Certain) . Because short sightedness eyes can be correct with a diverging or concave lens. (Almost certain) .
L5	A, (Almost a guess) . It might be letter A because a longsighted person can use convex lense. (A totally-guessed reason) .
L6	C, (Certain) . A person need a diverging/Concave if he/she cannot see distant objects for him/her to see distant objects. (Almost certain) .
L7	C, (Certain) . because it forms a small surface behinds the retina. (Almost certain) .
L8	A, (Almost a guess) .
L9	C, (Certain) . A person who cannot see distant object has is short sightedness and can use concave lenses. (A totally-guessed reason) .
L10	B, (Almost a guess) . Eye lense a. (A totally-guessed reason) .
L11	C, (Certain) . Because the image is formed before retina. (Almost certain) .
L12	B, (A totally –guessed answer) . Because the long sightedness should be seen concave.
L13	C, (Certain) . Because the lens is shorter, the person cannot see the far thing it only see the closer one. (Almost certain) .
L14	C, (Certain) . A concave is used to correctify some one who has a short sighted difficiency. (Certain) .
L15	C, (Certain) . Because rays of hortsighted travels in concave rays. (Almost a guess) .
L16	C, (Certain) . A short sightedness need lens of concave to see object far. (Certain) .
L17	B, (Almost a guess) . Because these person need along sighted so that he can see object around by a concave. (Almost a guess) .
L18	-----

L19	B, (Almost a guess) . Because the person will have long sightedness. (Almost a guess) .
L20	C, (Almost certain) .-----
L21	B, (Certain) . Concave lens its only give to the people with long sightedness defect. (A totally-guessed reason) .
L22	C, (Certain) . A person with short sightedness has to provided with a concave lense to see distant object clearly. (A totally-guessed reason) .

Question 15

L1	B, (Certain) . This is because light can only be fast when travelling in an empty space (vacuum). (A totally-guessed reason) .
L2	C, (Totally-guessed answer) . Because light travel faster in a vacuum. (A totally-guessed reason) .
L3	B, (Almost certain) . Because the speed of light in a vacuum is high then the speed light in glass. (Certain) .
L4	C,
L5	B, (-----) . The light travels faster in the vacuum because it does not require more particles to transport it. (Certain) .
L6	B, (Certain) . Because in the vacuum there are not particles. (Certain) .
L7	C, (Almost a guess) . Because light will be slower that travels in the straight line as the vacuum won't be straight. (Almost a guess) .
L8	-
L9	B, ((Almost certain) . Light travel in the air it has higher speed in the vacuum. (Certain) .
L10	B, (Almost guess) . Light travels more faster in vacuum than sound in the vacuum. (Almost certain) .

L11	B, (Certain) . Because a vacuum is an empty space without particles and therefore light can pass through. (Almost certain) .
L12	C, (Totally-guessed answer). Because there is no air particles. (Almost certain) .
L13	B, (Almost certain) . Because it is empty space. (Almost a guess) .
L14	B, (Certain) . Because we learnt that light is faster in vacuum and slow in solid objects. (Certain) .
L15	B, (Almost certain) . There is no object that can break the light in the vacuum. (Almost guess) .
L16	A, (A totally-guessed answer) . Light does not travel in the vacuum. (Almost a guess) .
L17	A, (Almost certain) . Because I think light can travel in a vacuum where there is an empty space or more particles. (Almost a guess) .
L18	-----
L19	B, (Certain). Because light travels faster in the vacuum because there is only air.
L20	D, (A totally-guessed answer) --
L21	A, (Certain) . A vacuum is an empty space. (Certain) .
L22	This is done because particles in vacuum are far apart. (Almost certain) .

APPENDIX H: Collated data from post-test

Collated data from learners' post test

Question 1

L1	B, (Certain). White paper will reflect more light in the darkness. Black paper will be a poor reflector of light because it only absorbs heat. Blue paper also a poor reflector of light as it is a mixture of different colours. (Certain).
----	--

L2	B, (Certain). I choose white paper because it reflect more light and the other colour are made up of many different colours. (Certain).
L3	B,(Certain). The blue paper absorb light and the black paper absorb light while the white colour paper does not absorb light it reflected all the light. (Certain).
L4	B, (Certain).Because the white colour reflect more light than other colours. (Almost certain).
L5	B, (Certain). The white paper will be clerely bbe seen because it reflects more light. (Almost certain).
L6	B, (Certain). Because white colour reflect more light that other colors. (Certain).
L7	B, (Certain). Because the white paper reflects more light than others. (Certain).
L8	B, (Almost certain). White paper can be easily be seen because it reflect light more than other papers. As most white things are shine also the paper will be more visible more than others paper.(Certain).
L9	B, (Certain). White surface reflect light more than the others. (Certain).
L10	B, (Certain). It's because white colours use to reflect more light than other colours. (Almost certain).
L11	B, (Certain). Because a white colour reflect more light rays to be observer. Blue and black paper colour absorb most of the light rays , so they are not easly to be seen. (Almost certain).
L12	B, (Certain). Because the white paper reflect light even during the night or when placed on a dark room. (Almost certain).
L13	B, (Almost certain). Because the white colour is easily to be seen in a dark room than others. (Almost certain).
L14	B, (Almost certain). Because blue and black colours they look like the darkness of the room that is why they can not be seen. (Almost certain).

L15	B, (Certain). White paper is a good reflector and it is visible during the night (dark). (Almost certain).
L16	B, (Certain). The white paper will be seen easily as it reflects light to the learners while the blue and black will absorb some incident rays. (Almost certain).
L17	B, (Certain). Because white colour reflects light easier than black and blue colour. (Almost certain).
L18	B, (Certain). Because the white colour reflects more light than other colours. (Certain).
L19	B, (Almost certain). Because white colour reflects light. (Almost a guess).
L20	B, (Certain). Because a white colour reflects light more than other colours. (Certain).
L21	B, (Certain). Because white colour reflects more light than the other two. (Certain).
L22	B, (Certain). I choose a white paper among the blue and black. This is because the white paper reflects more light than the other two, so it can be easily seen in a dark room because of its white colour.

Question 2

L1	A, (Almost certain). Think because, I know reflection is the only thing that makes the image of the zebra to be seen in the water. (Almost certain).
L2	B, (Certain). Because of reflection of light, light from one source hits the lake and then light reflects to the zebra and sees its image in the lake so the zebra may also see its image in water. (Almost certain).
L3	A, (Certain). Because the light from the source hits on the Zebra and it is reflected to the surface of the water to form an image in the water just like a mirror. (Certain).

L4	A, (Certain). The light rays hits the zebra and the spread into the water and now reflects into water and able to see the zebra's image in the water.
L5	A, (Certain). It is reflection because zebras are reflected by the water and their images can be seen in water. (Almost a guess).
L6	A, (Certain). Light from the source hits the zebra, then reflected into the water and back to the zebra so that it can saw it's image. (Certain).
L7	B, (Certain). The light rays hit the zebra and goes to the water surface and reflected. (Almost a guess).
L8	A, (Almost certain). As light travel from the source they hit on the object (zebra) and reflected in water and reflected back on you, to see the image formed in water. (Certain).
L9	A, (Certain). Light comes from the source e,g sun to the body of the animal and then reflected in water. (Certain).
L10	A, (Certain). Light rays hit the zebras reflected in to the water and form a image in water. (Almost certain).
L11	A, (Certain). Because the light rays hit the zebras and the shape and colour/image of the zebras will be seen on the water because water acts as a mirror/reflector.
L12	A, (Certain). It's reflection because when there is an source available and than even the sun heats the object than object reflect light into the water, make it for the zebra/object seen itself in the water. (Almost a guess).
L13	A, (certain). Because the light coming from the source to heat the zebra and reflect back to the water inorder to see the zebra image in water. (Almost certain).
L14	D, (Certain). Diffraction is the bending of light from one medium to another medium. (Almost certain).
L15	A, (Almost certain). Is the sending back of the lught, so the zebra image is sended back by the water that acts as a mirror. (Almost a guess).
L16	A, (Almost certain). Water is a transparent so as the incident rays reaches the zebra the zebra can reflected in water. (Almost certain).

L17	A, (Certain). Because reflection occurs when you look on an object and come back. (Almost a guess).
L18	A, (Certain). Because the light rays heats the zebras and from it heats the water and back to the zebras so that they can be reflected into the water. (Almost certain).
L19	B, (Almost a guess). Because reflection is the bending of light and the image is formed in the water. (A totally-guessed reason).
L20	A, (Certain). Because water surface acted as a mirror, simply because when light is supplied by the light source which can be a sun light rays hit the zebras and from the zebras it goes to the water surface where the image is formed. (Almost certain).
L21	A, (certain). Only in reflection where the image upright are formed there virtual. (Certain).
L22	B, (Certain). In short reflection is a straight back of light. The light came from the source and heat the animals and than reflected by the water and than to the eyes of a person to see the image in water. (Almost certain).

Question 3 (3.1)

L1	B, (Certain). The flash light should be aimed at his chin, only to be able to see where the mosquito bite is. (Certain).
L2	B, (Almost certain). The flash light should be aimed at his chin because its the part he want to see. (Almost certain).
L3	B, (Certain). Because he should aim at his chin so that light can be reflected by his chin to the mirror and back to his eyes to see himself. (Certain).
L4	B, (Almost certain). Light hits to Angela's chin and the reflects into the mirror and now he is able to see himself in a plane mirror. (Almost certain).
L5	B, (Certain). The flashlight should be aimed at his chin so that the chin will reflects light to the mirror and the mirror reflects that light into his eyes so that he can see the image of the mosquito. (Certain).

L6	B, (Certain). The flash light should be aim at his chin so that light from the flash light hits his chin/get reflected to the mirror and reflected back to him so that he can see himself on the chin. (Certain).
L7	B, (Certain). The light hits his chin and goes to the mirror and reflected back to his eyes and he can able to see his chin. (Certain).
L8	B, (Almost certain). As light travel in a straight line, Flashlight must be aimed on his chin so that it must reflected in a mirror and reflected back to his eyes that can make him see his chin in a mirror. (Certain).
L9	B, (Certain). For him to see his chin is when he only place the flashlight on the chin so that light can reflect in the mirror. (Certain).
L10	B, (Certain). Flash light which is a source of light has to aimed at the chin so that it can be reflected to the mirror for Angula to see his chin. (Certain).
L11	B, (Certain). Because the light from the torch need to hit Angula's chin first. Then image of his chin will than se on the mirror he hold. The light rays will than be reflected to Angula's eyes. Now he could see the image of this chin clearly. (Almost certain).
L12	B, (Certain). Because Angula wants to check his chin so he have to flash the light mostly on his chin and later check itself in the mirror. (Almost certain).
L13	B, (Almost certain). Because Angula was need to take a flashlight to light on his chin and light reflect back to the mirror. (----).
L14	B, (Certain). Because light has to come from the light source to the chin and reflected to the mirror and the mirror reflect it to the eyes and is whereby you can be able to see the chin. (Certain).
L15	B, (Certain). Point on the object that you want to see first so that it can be reflected in the mirror and reflected back to you. (----).
L16	B, (Certain). Angula has to torch on his chin inorder to see what is on his chin. As the light ender Angula's chin it can reflected to the mirror for him to see what on her chin. (Almost a guess).

L17	B, (Certain). Because he need to flashlight his self for the light to reflect back into his face and see. (Certain).
L18	B, (Certain). The flashlight should aim to his chin because if you touch on the mirror the reflected light bends away and he can't see his chin but if you touch onb the chin, the flashlight will be reflected in the mirror so that you can be able to see his chin. (Almost certain).
L19	B, (Certain). Because as he flash on the chin the light will reflected back to the mirror and he will see the chin in the mirror. (Almost certain).
L20	B, (Certain). This is simply because light rays have to hit your body first and from your body is where know it goes to the mirror and the mirror reflect light back to you and this enables you to see image in the mirror. (Almost certain).
L21	B, (Certain). Because light is reflected from the chin to the mirror. (Almost certain).
L22	B, the light from the source has to aimed at his chin so that the mirror can reflect it and than reflected to the person eyes to seen where the mosquito bites.

Question 3 (3.5)

L1	A, (Certain). Only able to see the mosquito bite when you hold the flash light aimed to the chin as seen in the diagram (a). (Certain).
L2	A, (Almost certain). He have to focus on his chin because its the part that has awakened by the mosquito and he has do that to be able to see it (chin). (Certain).
L3	A, (Certain). Because he aim at the mirror the light will not come with his image and can not see his image. The mirror will just reflect all the light to him and he can not see in the mirror again. (Certain).
L4	A, (Certain). Light hits the chin of a child and the spread into the mirror and reflects again back for you to see the image thoroughly. (Certain).

L5	A, (Certain). I am very sure because light from the light source (Torch) should be aimed on his chin the chin will reflect that light to the mirror, the mirror reflects the light into his eyes for him to see what he wants to observe. (Certain)
L6	A, (Almost certain). Light should travel from the flashlight, hits the point where you want to observe (chin),. Reflected to the mirror and reflected back to your eyes so that you can see yourself. (Certain).
L7	A, (Certain). Because the light will hit the chin first in order to be reflected by the mirror. (Certain).
L8	A, (Almost certain). For you to see your chin in a mirror during night, the light must travel straight to your chin, so that it can be easily visible reflected in a mirror and reflected also back to your eye and then you can see your chin easily visible. (Certain).
L9	A, (Certain). The flashlight must point on the chin and light reflect in the mirror and comes back to his eyes so that he can see himself. (Certain).
L10	A, (Certain). The light rays from the torch is aimed on the chin and then is reflected into the mirror from the mirror to the eye so that a person can see. (Almost certain).
L11	A, (Certain). Because if the torch touches the mirror it will reflect torch rays into the observer's eyes and he could not be able to see. (Certain).
L12	A, (Certain). You have to flash the light on your chin and after you check yourself in the mirror. (Certain).
L13	A, (Certain). Because the light bulb first touches you and light reflects to a mirror so that you can see yourself in the mirror. (Certain).
L14	A, (Certain). Because if you aim the light source to the mirror you can not see your chin but what you can see is only the reflected ray of light from the mirror. (Certain).
L15	A, (Certain). The light first hits on the object that you want to observe and hits the mirror and then goes back to you (Observer). (Certain).

L16	A, (Almost certain). For Hangula to see whats on his chin he need to torch to her chin, as the light enter Hangula's chin it be reflected to the mirror and Angula ca see whats on his chin. (Almost certain).
L17	A, (Certain). Because of the light to diverge along his force in order to be seen. (Certain).
L18	A, (Certain). Diagram A but described it because the flashlight touched to the chin and light reflected in the mirror and back to his eyes so that he can easily see his chin.
L19	A, (Certain). Because the light first hit the chin and than can be reflected back to the mirror. (Certain).
L20	A, (Certain). Because that is the way how light rays have to travel from the source to your body, to the mirror and back to your body. (certain).
L21	A, (Certain). Diagram A is almost showing what I explained in Question 3.3, As the light heats where the mosquito bites and than reflected by the mirror so the person can see. (Certain).
L22	A, (Almost certain). He is pointing the flashlight on his chin. (Almost certain).

Question 4

L1	B, (Almost a guess). I think the location of the image seen by Tangi is on the right side of that seen by Nangula because objects are placed directly in the middle of the plane mirror. (Almost a guess).
L2	B, (Almost a guess). This is because when you were at the left side of the mirror your image will be seen at right side because your left side might become your right side. (Almost a guess).
L3	B, (Almost certain). Because they are not siting at the same place so the pencil will be seen from the eye direction of Tangi and Nagula. (Almost certain).
L4	D, (Almost certain). The location of image shown by students is not the same ; because Tangi seen the image as it is on the left side of Nangula while Nangula seen the location of image as it is on the right side of Tangi. (Certain).

L5	C, (Certain). Because the position of the image seen by Tangi is not at the same position as seen by Nangula. (Almost a guess).
L6	B, (Almost certain). The image become laterally inverted, the location of the image on the right side seen to be on the left side and vice-versa. (Almost certain).
L7	A, (Almost certain). Because the two kids are in front and parallel to the mirror. (Certain).
L8	C, (Almost a guess).-----
L9	A, (Certain). Because they are all parallel to the mirror and the object is in between both of them. (Certain).
L10	B, (Almost certain). Tangi and Nangula are at different position and they are seeing the pencil at different position as Tangi will see it on right and Nangula see it on left side. (Almost certain).
L11	A, Because they are all parallel to the mirror and object (pencil) Therefore the image to be seen by them will be same. (Almost a guess).
L12	B, (Certain). Because Tangi sit on the left side edge of the table and obviously he has to see the object on her right side.(Almost certain).
L13	C, (Almost a guess). Because on the left side. (Almost a guess).
L14	A, (Almost certain). Because they are all in front of the mirror and the image in a mirror looks like the object always. (Almost certain).
L15	A, (Almost a guess). Because the angle of reflection is equal to the angle of incidence on both side of the boy and girl. (Almost a guess).
L16	B, (Almost a guess). The image seen by Tangi has to be on the right side because the object is. (-----).
L17	A, (Almost a guess). Because it must be the same because both student are sitting on the same distance. (Almost a guess).
L18	A, (Certain). Because they all parallel to the mirror. (Almost certain).

L19	A, Because they are at the same distance from the mirror. (A totally-guessed reason).
L20	C, (A totally- guessed answer). Because is made by the position of where the boy is sitting. (A totally- guessed answer).
L21	A, (Almost certain).all of the them they are looking in the mirror where the image is formed none of is sitting beyond the table. (A totally-guessed reason).
L22A	B, (Almost certain). The location of image seen by both students are the same because both students are parallel to the pencil.(Almost certain).

Question 5

L1	E, (Almost a guess). The image of the pencil won't be seen by either Nangula or Tangi because it is moved to the edge of the mirror, cannot be seen or either only when it is moved toward the middle of the mirror. (Almost a guess).
L2	A, (Almost a guess). Because the girl is almost at the beyond region of where the pencil is placed.(Almost a guess).
L3	A, (certain). Because the pencil not at angle where the girls eyes can see in the mirror but at the angle where the boy can see. (Certain).
L4	C, (Certain). Because light make it possible for us to see things, either by reflection of light or by refraction. (Almost certain).
L5	A, (Certain). Only be boy could able to see the image because the object is on the front of the mirror so the light from the image can only be reflected to the boy> (Almost a guess).
L6	B, (Almost Certain). The image could be seen by the girl because the girl it become laterally inverted. (Almost certain).
L7	A, (Certain). Because the girl is beyond the edge of the mirror and the boy is facing the mirror on the other side before the edge. (Certain).

L8	A, (Certain). Because light travels in straight line, a girl can't see the image because it is parallel to the pencil (object), but the boy can easily see the image formed in a mirror because the angle of incidence ray is equal to the angle of reflection. (Almost certain).
L9	A, (Certain). As he moved on the edge, only him can see the image by reflection. (A totally-guessed reason).
L10	A, (Certain). Only a boy can see it because he the it from other side of the mirror. (--- ---).
L11	A, (Certain). Because the pencil is on an opposite side with the boy so he could see the image. The girl ca not see the image because she is parallel to the pencil except the mirror. Therefore it is impossible for her to see the image formed. (Almost certain).
L12	A, (Almost certain). Because the boy sit on the left side of the table and the pencil is located on the edge of the mirror meaning on a boy can see the pencxil imn the mirror. (Almost certain).
L13	C, (Almost certain). Because a Boy and a girl are all sitting on the same place. (Almost certain).
L14	C, (Certain). They can all see the image but at different position in the mirror. (Certain).
L15	A, (Certain). The girl is on the edge of the table where pencil is and the angle of reflection is not equal with the angle of incident. ((Almost a guess).
L 16	A, (Almost a guess). The boy can be able to see object in the corner because the boy and the pencil are all at the same angle. (Almost agues).
17	A, (Almost certain). Because the pencil now is perpendicular to the mirror thuy why the boy can see it while the girl cannot see the object because the pencil is behind the mirror. (Almost certain).
L18	A, (Certain). Because the image viewed on the left side in the mirror. (Almost a guess).
L19	A, (Almost certain). Because the boy is at the edge to the reflected ray of the pencil. (Almost a guess).

L20	A, (Certain). The boy can see the image because when light rays are reflected away from the mirror, they go differently to his eye. The girl cannot see the image because her and the mirror are all beyond the edge of the mirror and the same side. ((A totally-guessed reason).
L21	A, The pencil was moved forward the girl, now the boy can see the image because the image formed in the mirror is perpendicular to his eyes. ((Almost a guess).
L22	A, (Almost certain). The boy will see the image because of reflection light bends toward the mirror so the boy can easily see it unlike the girl who is at the edge of the mirror. (Almost a guess).

Question 6

L1	C, (Certain). The image will stay in the same place because even if you remove the bulbs it won't change unless you move the pencil. (Certain).
L2	C, (Certain). Because even though the lamp is moved any way and the object does not move it will stay at the same place as object. (Almost a guess).
L3	C, (Certain). Because the mirror and the pencil did not move but the light has moved. (Certain).
L4	B, (Certain). Because the more you raise the lamp higher, then the image of the pencil will move down and vice versa. (Certain).
L5	C, (Certain). It will stay in the same place because the position of the light source (Bulbs) has no any image. (Certain).
L6	B, (Almost a guess). The reflected ray seem to be at the base of the mirror. (Almost a guess).
L7	A, (Almost certain). Because as the light rays increase the image will be bigger. (Almost certain).

L8	C, (Almost certain). As I know the light source these note effect the position of the image, because light can come from any angle but the object is reflected by how is it. (Almost certain).
L9	B, the higher the position of the lamp, the lower image will be.(A totally-guessed reason).
L10	C, (Certain).Light source does not affect the location and the image of the objects.
L11	Because the image on a plane mirror is not affected by the changing position of the source of light. So, it will remain the same. (Certain).
L12	B, (Certain). Obviously it will move down because of the changing position of the lamp. (Certain).
L13	B, (Certain). Because if you are making the experiment and you move up a light source the pencil in the mirror will always move down. (Almost certain).
L14	B, (certain). Is because when light source is far the image of the object decrease. (Certain).
L15	C, (A totally-guessed answer). The image depend on the movement of the object. (Almost a guess).
L16	A, (Almost a guess). As the source of light move up the image of the pencil in the mirror will also see to be up in the mirro. (A totally guessed reason).
L17	C, (Almost a guess). Because if you raise the lamp the pen cannot move at any point.
L18	C, (certain). The location stays the same in location because its not movin g but what is moving is the light source. (Certain).
L19	C, (A totally-guessed answer). Because the lamp is only one moved but not the pencil as a result it will stay in the same place. (A totally-guessed reason).
L20	B, (Almost a guess). I think its only because the image formed on the mirror acts as shadow, Because shadow cannot be on the same side as the light source so that is why when the light source is raised so the image will move down.(A totally-guessed reason).

L21	C, Because only the light which moved not the object the high rays are still focusing on the same direction. (Certain).
L22	C, (Certain). It will stay in the same place because the laws of light says the distance of the objects is the same as the image form by the mirror. (Almost certain).

Question 7

L1	C, (Certain). The image will remain unchanged because even if you raise a lamp higher the image won't change, unless may be you touch the pencil itself. (Certain).
L2	C, (Certain). This is because eventhough you move e a pen a bit the height does not change. (Almost certain).
L3	C, (Certain). B because the pencil did not move back ward or anywhere it is just the light source that has moved. (Certain).
L4	C, (Almost certain). Because the image formed in a plane mirror is of the same size as the object. (Certain).
L5	B, (Almost a guess). As the bulb goes up the image's height will goes down, they are inversely proportional. (Almost a guess).
L6	B, (Certain). The angle of incidence will be larger than the angle of reflaction. (Almost a guess).
L7	A, (Almost certain). As the light glass higher the image grows bigger. (Almost certain).
L8	C, (Almost certain). Light have not effect the size or position of the image formed, but light is only there for the object to be visible and reflected in a mirror according to how is it , placed or size.
L9	B, (A totally-guessed answer). As the lamp is raised up, the image will become shorter. (A totally-guessed answer).
L10	C, (Almost certain). Nothing will happen the height will remains as is because light does not cause any change on the object and image. (Almost certain).

L11	B, (Almost a guess). Because the light source will be only torching at the top of the object and the image to be seen will look shorter. Unless, when the light source is at the same height with the object, where it is possible for the image and object to be of the same height. (Almost a guess).
L12	A, (Almost a guess). The image will become longer because of the light rays that travel through different medium or rays. (Almost a guess).
L13	B, (Almost a guess). -----.
L14	B, (Certain). Because if the light source is far the image of the object decreases. (Almost certain).
L15	C, (A totally-guessed answer). The image wouldn't change if the lamp raised because the image depend of the object. (Almost a guess).
L16	A, (almost a guess). As the light source move away and up the image will see longer because there is a long distance between the pencil and the source of light. (A totally-guessed reason).
L17	A, (Almost certain). Image will be longer if you raise because the higher you go the longer it will be above the object, seems to be long due to the refracted. (Almost certain).
L18	C, (certain). Because if you move /raise the lamp higher the pencil will be reflected the same and if you move the lamp downward across the pencil it will be reflected still same and the image appears the same because nothing have changed. (Almost certain).
L19	A, (Almost certain). Because the angle of reflection will be high so the height of the image will become longer as the reflection will be higher. (A totally-guessed reason).
L20	B, (Almost a guess). Same answer as in 6.3. (A totally-guessed reason).
L21	C, (Almost certain). The image does not change only the light which is raised, during reflection light the size of the object does not change. (Almost certain).
L22	C, (Certain). The image will remain unchanged, because the laws of light states that the size of the object is the same as image in the mirror. (Almost certain).

Question 8

L1	C, (A totally-guessed answer).It want change it will remain unchanged because its well known that image of objects do not change when light is fixed. (A totally-guessed reason).
L2	C, (Certain). The height of the image will seems like that one of the object even position is being changed. (Almost certain).
L3	B, (Almost certain). Because the pencil has moved away from the mirror the image become smaller because the pencil is a bit distant from the mirror. (Almost certain).
L4	C, (Certain). Image formed in a mirror of the same size as the object. (Certain).
L5	B, (Almost certain). Because as the object is far from the mirror the image will also get smaller. (A totally-guessed reason).
L6	C, (Almost certain). The distance from the image stays the same to that from the object. (Almost certain).
L7	B, (Almost certain). As the objects moves further the image goes shorter/smaller. (Certain).
L8	B, (Almost certain). As most things far are seems smaller , the mirror will also reflect the small things the distance of the image and object will be the same or equal from the mirror. (Almost certain).
L9	A, (Almost certain). As the distance of the object changed, the image will become longer. (Almost certain).
L10	C, (Almost certain). Only the distance increase between the mirror and object but the height of the image remain as they are. (Almost certain).
L11	C, (Almost certain).Because the image formed in a plane mirror is affected by the changing position of the object. As you move the object closer to the mirror it will look bigger than as you move it away. (Almost certain).
L12	B, (Almost a guess).The image will become shorter because of the distance changed by the object from the mirror. (Almost a guess).

L13	C, (Almost certain). Because no change. (Almost certain).
L14	B, (Certain). The more the light is far the shorter the image is and the closer the light is the longer the image is. (Certain).
L15	A, (Almost a guess). The image will change because the object move. (Almost a guess).
L16	B, (A totally-guessed answer). There is a short distance between the observer and the mirror so the image will seen shorter than the object in actual. (A totally-guessed reason).
L17	C, (Almost certain). Will remain unchanged due to the futher moving mirror, object will never move, (Almost certain).
L18	B, (Certain). Because if you move the pencil away from the mirror obvious the pencil will be reflected less, less will reach at it and it will be shown small. (Almost certain).
L19	B, (Almost certain). Because the pencil will not be in the angle of reflection and only a small part will form a image. (A totally-guessed reason).
L20	C, (A totally-guessed answer). If it is a little further from the mirror it will not affect the image unless if it is moved more. (A totally-guessed reason).
L21	C, (Almost certain). The image does not increase in height because image which are formed are not changing in size. , (Almost certain).
L22	C, (Almost certain). Still nothing will happens as the laws of light states that angle of reflection is equal to the angle of incidence so the image remain unchanged. (Certain).

Question 9

L1	C, (Certain). Even though the observer move a little bit forward. Or back ward the location of the image of the image will stay at the same because there is nothing done at the image, It is only the observer who does a job. (Certain).
L2	A, (Certain). Because they are too closer to the mirror. (Almost agues).

L3	C, (Certain). Because the pencil is not moved so the image will stay at the same location in the mirror. (Certain).
L4	C, (Certain). Some distance between image and the object. (Certain).
L5	B, (Almost a guess). As the bulb goes up the image's height will goes down, they are inversely proportional. (Almost a guess).
L6	C, (Almost certain). The distance from the image to the object is the same as the distance from the object to the observer. (Almost a guess).
L7	A, (Certain). Because the closer you are at the mirror and the closer the image will approach. (Almost certain).
L8	C, (Certain). Image of the pencil forward in a mirror will not change because pencil is also not change only the observer come move but this is not affecting the image formed. (Almost certain).
L9	A, (A totally-guessed answer). As the observer move from the mirror, the image will retreat from the mirror. (A totally-guessed reason).
L10	C, (Certain). It because the location of observer do not affect the image of the object in the mirror. (Almost certain).
L11	C, (Certain). Because the image formed an a plane mirror is not affected by the changing position of the observer. Unless he/she can change the position of the pencil. (Almost certain).
L12	A, (Certain). Because the observer retreats from the mirror. (Almost certain).
L13	C, (Almost certain). Because the pencil stand where there was. (Almost a guess).
L14	C, (Certain). Because the mirror and a pencil do not move but what move is only the person who is observing. (Certain).
L15	C, (Almost a guess). The distance between the observer and the object t does not effect the image. (A totally-guessed reason).

L16	A, (A totally-guessed answer). Because there is a long distance between the observer and the pencil in the mirror. (A totally-guessed reason).
L17	B, (Almost certain). It will approach the mirror while its moving away or further than the normal place. (Almost a guess).
L18	C, (Certain). Because the lamp and the pencil are not moving and what changes the position is the observer. (Almost certain).
L19	A, (A totally-guessed answer). Because the observer moves away from the mirror and can no longer see the image in the same position. (A totally-guessed reason).
L20	C, (Almost a guess). Because the position of the observer does not affect the image when he/she is retreats, it can only affect the image when he/she is moving on the sides.
L21	C, (Almost certain). The location will not change because you did not change the distance of the object. (Almost certain).
L22	C, (Certain). It will stay at the same location, as only the observer has move but not the object. (Certain).

Question 10

L1	B, (Almost a guess). I think the answer is in B, because the object is placed near the mirror and its image it is reflected on the other side of the mirror. (Almost a guess).
L2	B, (Almost certain). The image will be as same as possible to the distance from the mirror to the object. (Almost a guess).
L3	B, (Certain). Because the distance and size of the image and object should be the same is just that the right side of the object becomes the left in the mirror. (Certain).
L4	(Certain), Because left becomes right and right becomes left. (Certain).

L5	B, (Certain). The image is B, because the right side of the object seems as the left side of the object and the distance between them from the mirror (object & image) is equal. (Certain).
L6	D, (Certain). The image will be seen at D because of reflection. (Almost a guess).
L7	B, (Certain). Because the distance between the object and the image is the same. (Certain).
L8	B, (Certain). Position and size of the object are use to be the same as the image formed in a mirror. B is the image formed for the object indicated.(Almost a guess).
L9	B, (Certain). The image will be formed behind the mirror and is laterally inverted and is virtual. (Certain).
L10	B, (Certain). The distance between the object and mirror is the same distance of the image. (Certain).
L11	C, (Certain). Because the object angle image formed shows the same distance of angle. (Almost certain).
L12	B, (Certain).Because, the object has to be formed in a plane mirror in such a way. (A totally-guessed reason).
L13	B, (Almost certain). Because the object does not change, it is same size. (Almost certain).
L14	B, (Certain). Because the image has to be same distance as the object from the mirror. (Certain).
L15	C, (Certain). The angle of reflection must be equal with the angle of incidence. (Certain).
L16	A, (A totally-guessed answer). Object has to be on the same position as it appear in the mirror. (A totally-guessed answer).
L17	A, (Almost a guess). Because the object should be the same like the one occurs in the mirror and proportional (Almost a guess).

L18	C, (Certain). Because the object has been reflected in the mirror and the light returns back and form an image at that position. (Almost certain).
L19	-----
L20	B, (Certain). Because there distance between the image and object are equal. (Certain).
L21	A, (Almost certain). Because it has the same distance virtual and upright. (Almost a guess).
L22	D, (Certain). The size of the image is equal to the size of the object as it appears in the mirror.(Almost a guess).

Question 11

L1	D, (Certain). All the objects are able to reflect light rays as they are all made up of different materials. Thats why we see them is only because they reflect light. (Certain).
L2	D, (Certain). Because any object can able to reflect light. (Almost a guess).
L3	D, (Certain). Because they all can be seen is just that they do not reflect light at the same directions. (Certain).
L4	A, (Certain).Because every object (thing) that we can able to see reflects light for it to be easily seen. (Certain).
L5	D, (Certain). It is all of the because can be seen all and this is because they reflects light for them to be seen. (Certain).
L6	D, (Certain). Because we see things because of reflection, so if they could not reflect, then they won't be seen. (Certain).
L7	B, (Almost Certain). Because the silver spoon is shine. (Almost certain).
L8	C, (Almost certain). Because it reflects light. (Almost certain).
L9	D, (Certain). All the white and shiny object reflect the light rays. (Certain).

L10	B, (Almost a guess). Only silvers are good reflector of light rays and the are not good absorber.(Almost certain).
L11	C, (Certain). Because the mirror reflects light at different speed and according to the distance. (Certain).
L12	D, (Almost certain). Light will reflect on all because they are not transparent, means light rays will not bent or spread but will reflect once approach those objects. (Almost certain).
L13	C, (Almost a guess). Because a mirror is a good reflector of light.(Almost agues).
L14	C, (Almost a guess). Because does not absorb light. (Certain).
L15	D, (Certain). All surfaces reflect light. (Certain).
L16	C, (Certain). Becauseae it is shinny. (Almost certain).
L17	D, (Ceratain). Simply because all the surface area reflect light. (Certain).
L18	C, (Almost certain). Because light cannot travel through a mirror. (Almost certain).
L19	B, (Certain). Because shinny surfaces are those that reflect the light and silver is also shinny. (Certain).
L20	C, (Certain). Mirrror is a trans-parent object and is also source of light. (Certain).
L21	A, (Certain). Because woody objects are bad conductors of heat and so they receive sun rays or heat and they send it back. (Certain).
L22	B,C, (Certain).Silver colour is a good reflector, and this is the same to a mirror. (Certain).

Question 12

L1	B, (Certain). Angle of incident is equal to angle of reflection. (Certain).
L2	B,(Certain). Because angle of incidence is always equal to the angle of reflaction. (Certain).

L3	B, (Certain). Because angle of incidence is equal of reflection. (Certain).
L4	B, (Certain). Because the angle of reflection is equal to angle of incidence. (Certain).
L5	B, (Certain). Because angle of incident ray is equal to the angle of reflection. (Certain).
L6	B, (Certain). Because angle of incident is ray is equal to the reflected angle. (A totally-guessed reason).
L7	B, (Certain). Because the angle of incident ray is equal to the equal of reflected ray. (Certain).
L8	B, (Almost certain). Because the light of incident rays is equal or same as the light of reflected rays.(Almost certain).
L9	B, (Certain). The incident ray is equal to the reflected rays. (Certain).
L10	B, (A totally-guessed answer). Reflection forms equally opposite angles. (Certain).
L11	B, (Certain). Because the angle of incident is equal to the angle of reflection. (Almost certain).
L12	B, (Certain). Angle of incident is equal to angle of reflection ($r=i$). (Certain).
L13	B, (Almost a guess). Because the angle of incident is equal to the angle of reflection. (Almost a guess).
L14	B, (Almost certain). Because the angle of incident ray is equal to the angle of reflection. (Almost certain).
L15	B, (Certain). The angle of incident is equal to the angle of reflection. (Certain).
L16	B, (Certain). Because the angle of incident is equal to the angle of reflection. (Certain).
L17	B, (Certain). Angle of incident is equal to the angle of reflection. (Certain).
L18	B, (Certain). Angle of incident is equal to angle of reflection. (Certain).
L19	C, (Almost certain). If the value of the actual angle is 30 degree, you have to add another 30 degree to get 60 degree. (Almost certain).

L20	B, (Certain). The angle of incident rays is the same as angle of reflection. (Almost certain).
L21	B, (Certain). It is because angle of reflection is equal to the angle of incidence. (Certain).
L22	B, (Certain). Angle of reflection is equal to the angle of incidence. (Certain).

Question 13

L1	D, (Certain). Refraction is the bending of light, light has to bent when travelling in the different medium. (Certain).
L2	C, (Certain). Yes, because it travel from a more denser to a less denser area(Certain).
L3	D, (Almost certain). Refraction is when the light rays bend as it enters a different medium. (Almost certain).
L4	D, (Certain). Because Refraction is a spread of light. (Almost certain).
L5	D, (Certain). Because refraction is when the light passes through different mediums and the light bends when passing when through the glass. (Certain).
L6	D, (A totally-guessed answer). ----- (A totally guessed reason).
L7	B, (Almost certain). Because Dispersion is split at changing colour. (Certain).
L8	C, (Almost certain). ----- (-----).
L9	D, (Certain). When light rays travel from the air into the glass it bents toward the normal line and when it travel from glass to air it bent away from the normal line. (Certain).
L10	B, (A totally-guessed answer). Because light travels from into glass its speed changes and cause effect of Dispersion white rays. (Certain).
L11	D, (Certain). Because it use to bent when the reach different mediums. (Almost certain).

L12	D, (Certain). Is refraction-the bending of light rays due to change in velocity (speed).
L13	A, (Almost a guess). -----(Certain).
L14	A, (Almost a guess). Light change because of velocity or dense of object. (Certain).
L15	D, (Certain). Refraction bends light rays when travelling in a different medium with a different density. (Certain).
L16	C, (Almost certain). Because it reflection will band away from a normal line. (Almost certain).
L17	D, (Certain). Because the bending of light is caused by refraction and this happen due to change in speed as it passes different mediums. (Certain).
L18	D, (Almost certain). Because of the change in velocity. (Almost certain).
L19	D, (A totally-guessed answer).Because when something is reflecting g light we say reflection and when we talk about speed we have to say reflection. (A totally-guessed reason).
L20	D, (Certain). Glass is trans-parent therefore light can pass throught. (Almost a guess).
L21	B, (Almost certain). It is because dispersion cause spectrum colours which appears on the glass when light has travelled from air. (Almost certain).
L22	D, (Certain). Speed of light rary according to different mediums. (Certain).

Question 14

L1	D, (Almost a guess). Need convex lens inorder image to be formed at the retina and to see what is far. (A totally-guessed reason).
L2	C, (Certain). Because only concave lens which can be used by short sightedness people. (Almost certain).
L3	C, (Certain). Concave glass are used by people who have short sightedness for them to be able to see distance objects.

L4	A, (Almost a guess). -----(----).
L5	D, (Certain). Short sightedness people only see objects that are near them and sometimes seems to be smaller than normal. (Almost certain).
L6	B, (A totally-guessed answer).----- (A totally-guessed reason).
L7	B,(Certain). Because people who have long sightedness cannot see things that are far, while short sightedness can the object that are far. (Certain).
L8	D, (Almost a guess).-----.
L9	A, Because light meet before the retina. (Almost certain).
L10	C, (Almost certain). Because short sightedness on concave lens the affect person not to see well.(Almost certain).
L11	D, (Certain). Because short sightedness is person can be given a lens of convex to see well.
L12	C, (A totally-guessed reason). ----- (----).
L13	A, -----
L14	D, (Certain). Because an eye to correct it you need convex if it is a short sightedness.
L15	C, (Certain). If a person cannot see distant object clearly then is shortsightedness and needs concave lens that diverge rays to be seen beyond the retina. (Certain).
L16	B, (Certain). For him to see object which at a long distance from him. (Almost certain).
L17	C, (Almost certain). A short sighted person in a convex lens so that he/she can see distant things.
L18	A, (A totally-guessed answer). Because it bring objects closer. (A totally-guessed reason).
L19	B, (Certain). Because a long sightedness person is the one that will see objects very clearly when he is far object. (Almost certain).
L20	C, Certain). Concave lens so that the image can be formed at retina. (Almost a guess).

L21	C, (Certain). It is because lens are able to extend the distance of the shortsightedness person. (Certain).
L22	D, (Certain). -----. (-----).

Question 15

L1	B, (Almost a guess). In a vacuum there are no air particles which broke the light. (Almost certain).
L2	B, (Certain). Because in a vaccum there is nothing to lock the air particles, is an empty space. (Certain).
L3	B, (Certain). In the vacuum there no particles, so there will be no any brokage of light rays.
L 4	B, (Certain). Because vacuum is the empty space without particles and the light can travel in fast.
L5	B, (Certain). Because vacuum does not have any particles and its less denser than the glass.
L6	C, (A totally-guessed answer). I have no valid reason why. (A totally-guessed reason).
L7	A, (Certain). Because in the vacuum there is no air. (Certain).
L8	A, (Almost a guess). Vaccum is a space where there is no any gases but light travel in place where there is oxygen and carbon dioxide.
L9	A, (---). Because there are no particles. (Certain).
L10	B, (Certain). Light are faster in the vaccum because vacuum is light conduct. (Certain).
L11	A, (Almost certain). Because in the vacuum there are not particles inside to carry out light there.

L12	B, (Certain). Light will travel faster in the vacuum because there are no particles in the vacuum and in the glass there is. (Certain).
L13	A, (---). Because light cannot pass through a vaccum. (Almost a guess). (Almost a guess).
L14	B, (Certain). Light travel only in a vacuum like in air. (Certain).
L15	B, (Certain). It travels faster because the vacuum is an empty space with no particles that can decrease the speed of light , so light faster in a vacuum. (Certain).
L16	A, (Certain). There is no particle to carry vibration. (Certain).
L17	B, (Certain). Because light can travel in any medium. (Certain).
L18	B, (A totally-guessed answer). Because in a vacuum there no air particles. (Almost certain).
L19	B, (Certain). Because light travel in a vaccum. (Almost certain).
L20	B, (Certain). Light travel faster in the vacuum only the sound can not travel in thevaccum. (Almost a guess).
L21	B, (Certain). Because light travels with a higher speed since there are no other things. (Almost certain).
L22	B, (Certain). Vaccuum consist of gas particles that are loosely arranged.(Certain).

APPENDIX I:

APPENDIX I: Transcribed data from stimulated recall interview based on pre-test result

Transcribed data from learners' stimulated recall interview based on their pre-test responses

Follow up questions for each learner.

Question 1:

L1: What do you mean by saying white colour is more clearly visible in darkness? Can you please elaborate your answer?

L2: You indicated that white paper can be easily seen while dark colour cannot be easily seen. Explain your answer in details.

L3: Based on your answer, you stated that white paper reflects light? Explain how it happens?

Learner	Responses
L1	I mean white colour reflect light than other colours. the colour like black and blue do not reflect light
L2	White colour reflects more light. Dark colours... such as black and blue do not reflect light at all.
L3	When light hit the white paper, it is send back to eyes and the paper can be seen. Blue and black paper are so dark they absorb light, but sometime they reflect light so that we see them when there is light

Question 2:

L1: What do you mean by saying reflection is well known to be sending back image?

L 2: Explain how does the reflection of light generate an inverted image of zebras' drinking water in the lake?

L3: Why do you choose option 'C' as the answer of your choice in this question?

Learner	Responses
L1	It sends light back which carry image so that the person can see it easily
L2	The reflection of light creates a shadow of zebras in water because the water is clear andokey.

L3	Because water behaves like lenses to form up this image of the zebras in the lake which is inverted.
----	--

Question 3:

L1: Based on your answer, explain how does Angula able to see his chin in the mirror very clearly if the flashlight is aligned parallel to the mirror?

L2: Explain, Why do choose option 'B' as the answer of your choice instead of other options?

L3: Explain, Why do you choose option 'C' as the answer of your choice in this question instead of other options?

Learner	Responses
L1	When the torch is parallel to a mirror it provides equal light to both side. Some light goes to the mirror some goes to the chin, so that every thing is seen well.
L2	Because mirror reflect light which come back to the eye. If the flash is aimed at his chin he cannot able to see his chin in the mirror because the room is dark.
L3	Because light should hit the chin, send to the mirror and reflected to the eye for the chin to be seen

Question 4:

L1: What do you mean by saying the location of the images seen by both students are reflected to the other side? Which side do you refer to as other side?

L2: Explain, why do you choose option 'A' as the answer of your choice in this question instead of other options?

L3: Based on your answer, explain why you choose option 'B' as the answer of your choice in this question instead of other options?

Learner	Responses
L1	I was confused, I do not know the true answer. Other side may be behind the mirror
L2	Because both students are sitting at the same side of the table with the same distance from the mirror and pencil. Light reflected from the mirror will equally reach their eyes
L3	May be is because the pencil is in front of the mirror but not touching it. They see image in different positions

Question 5:

L 1: Explain more on how sure are you that neither of the two students can see the image?

L 2: Based on your response, explain more why only the boy can see the image but the girl cannot see it?

L 3: Based on your response, explain more why only the boy can see the image but the girl cannot see it?

Learner	Responses
L1	Because when I see this picture the pencil is outside the mirror. Nobody is able to see its image.
L2	Because the girl is close to the pencil and the pencil is outside of the mirror. The light reflected from the mirror will not reach the girl, but it only goes to the side of the boy.
L3	Because they are not sitting in the same angle and the angle of reflection is not 90 degree

Question 6:

L1: Explain how does the change in the location of light source (lamp) influence the location of image of the pencil in the mirror?

L 2: Explain how does the change in the location of light source (lamp) influence the location of image of the pencil in the mirror?

L 3: Explain how does the change in the location of light source (lamp) influence the location of image of the pencil in the mirror?

Learner	Responses
L1	When the lamp raised up the image also move up and when the lamp moved down the image also move down
L2	When the lamp move up, it causes the image in the mirror to move down because light is facing down also
L3	It has no effect. When the lamp is moved at different positions, the image remains on its positions because the object is not moved, but remains fixed.

Question 7:

L 1: Explain your answer, why do you say the image will become longer when the lamp is raised a little bit higher? How does it happen?

L 2: Based on your response, explain why you do say the image of a pencil seen in the mirror remains unchanged even if the lamp is raised a little bit higher?

L 3: Explain why do you choose option 'C' as an answer of your choice in this question?

Learner	Responses
L1	May be the image stretched following the direction of the lamp
L2	Because the pencil did not move, so the image stays where it is. If the pencil was moved, then the image should also move.

L3	The change in the location of the source of light does not change the size and shape of the image in the plane mirror
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Question 8:

L 1: In your response, you indicate that when the pencil moved a little further from the mirror, the image of the pencil become shorter due to the decrease in distance. Explain how does it happen?

L 2: In your response, you indicate that when the pencil moved a little further from the mirror, the image of the pencil become shorter due to the decrease in distance. Explain how does it happen?

L 3: What do you mean by saying the far the object the shorter the image in the mirror? Explain your answer in details.

Learner	Responses
L1	Because when you see something far in the mirror is always small. The eyes cannot see it well because it is far and look short.
L2	Because the visibility of light become not clear. The image may look small and short
L3	If the pencil is moved further from the mirror, the distance between the mirror and pencil increased and the reflected light travel longer distance to the reach the eye and the image will look shorter because it is far.

Question 9:

L 1: Based on your answer, Explain how does the image of the pencil retreat from the mirror the mirror when the observer move a little further from the mirror?

L 2: Based on your answer, explain how does the image of the pencil retreat from the mirror when the observer move a little further from the mirror?

L 3: Based on your answer, explain how does the change of the position of the observer affect the location of the image of the pencil in the mirror?

Learner	Responses
L1	The image also move away from the mirror on the other side because the observer also moved away from the mirror on another side of the mirror
L2	When the observer moves backward, the image in the mirror will also move backward. I don't know how it happen, may because of the distance which was increased.
L3	It does not does not cause any change because the pencil did not move.

Question 10:

L 1: What do you mean by saying only the objects that are near the plane mirror are able to form image?

L 2: Why do you choose option 'D' as it represents the correct position of the object's image in the plane mirror?

L 3: What properties of image by the plane mirror do you consider when you choose option 'B' as the represents the correct position of the object's image in the mirror?

Learner	Responses
L1	I don't know the really answer here. These pictures are confusing me and I can't tell which one image.
L2	Because it is in front of the mirror, in the mirror image can appear in front of the mirror.
L3	The distance between mirror and object should be should be equal to that of between mirror and image. The image should be having equal size as object but left appear to be the right side.

Question 11:

L 1: In your response, you have indicated that wood is a poor conductor of heat, thus it is able to reflect light. How do you relate the ability of a material to reflect light and its heat ability to conduct heat?

L 2: In your response, you have indicated that mirror is the only object that is able to reflect light. Explain what happen to others in the list such as wooden table and silver spoon?

L 3: In your response, you have indicated that mirror is the only object that is able to reflect light. Explain what happen to others in the list such as wooden table and silver spoon?

Learner	Responses
L1	I made mistake, it is not wood but the correct answer should be mirror because it has silvery surface to reflect light.
L2	Mirror reflects light because it is shiny. Wood and silver absorb light, but silver also reflect light but not like the mirror.
L3	Wooden table absorb light. Silver absorb some and reflect some light and mirror reflect almost all light rays.

Question 12:

L1: Based on your answer, explain why angle of incidence is equal to the angle of reflection?

L 2: Based on your answer, explain why angle of incidence is equal to the angle of reflection?

L 3: Based on your answer, explain why angle of incidence is equal to the angle of reflection?

Learner	Responses
L1	Because the normal line cuts them into two equal parts
L2	Because the normal line divided them into two equal angles

L3	Because they are always equal on a plane mirror and it is stated in the law of reflection.
----	--

Question 13:

L 1: What do you mean by saying light only travels a short distance to hit the glass?

L 2: What do you mean by light only travel in a vacuum? Explain in details.

L 3: Based on your answer, explain what do you mean by reflection is the movement of light from air into a different medium. Explain how it happens?

Learner	Responses
L1	I don't really know the answer, but the speed changes because in the glass the distance is short.
L2	The vacuum speed up the travelling of light. Diffraction is when light changes its speed
L3	The light bends when travelling from air into other materials. But I don't know what cause light to bend.

Question 14:

L 1: From the diagram what tells you that it shows a long sightedness? And explain how does convex lens can be used to correct it?

L 2: Based on your response, explain how the concave lens can be used to correct short sightedness?

L 3: Based on your response, explain how the concave lens can be used to correct short sightedness?

Learner	Responses
L1	I just guessed, I have no ideas sir.

L2	Concave lenses enlarge the size of object so that they can be seen even if they are far.
L3	It makes things look bigger to be seen well.

Question 15:

L 1: Based on your response, explain more in details why do you say light can only be faster when travelling in empty space (vacuum)?

L 2: Explain more in details, why do you say light travel faster in a vacuum?

L 3: Explain more in details, why do you say light travel faster in a vacuum?

Learner	Responses
L1	Because the vacuum is empty, there is nothing, thus why light just travel very fast in it.
L2	Light travels faster in vacuum because there are no air particles. The air reduces the speed of light.
L3	The vacuum increases the speed of light and glass reduces the speed of light because glass is thick.

APPENDIX J: Transcribed video-taped lessons stimulated focus group interview

Video-taped lessons focus group stimulated recall interview

Key: R= Researcher

L= Learner

FG=Focus group

Lesson 1: Stimulated recall interview

Topic: Reflection of light

R: Good afternoon learners!

FG: good afternoon Sir!

R: How are you?

R: Very well, I am fine. So I feel so honoured to attend the lesson with you. It was wonderful. So now we are going to watch the video-taped lesson and I am going to ask you some questions for more clarities and further explanations from you. I will need you to elaborate more.

R: What do you mean by saying light makes things look shinny?

L: Ok, I wanted to say in darkness, you cannot see things, but when you light the candle things can be seen.

R: Ok, you said candle light enable things to be seen in darkness. Can you briefly explain how does it happen?

L: Mhh.... ok, light hit things and make the visible.

R: Most of you were pointing the torch flash on the mirror for you to see the image of the yellow sticker on your chest in the mirror. What was your intention to point it to the mirror?

L: We thought the mirror; the mirror should be visible for things to be seen in it.

R: All of you agreed that things are able to be seen due to reflection of light. Are there other objects that can be seen directly not depending on the reflection of light from other sources?

L: No! No! (Shouting together), light is very important for making things visible.

L: Sorry sir! The sun does not reflect light, buirt it produces its own light, we can see it in that way.

R: How do we call these objects that produce their own light like the sun?

L: Yes! The sources of light.

R: How do we scientifically call the sources of light?

L: Ooo! I remember it, mmh....Luminous objects.

R: This is the end our video and interview. I really thank you for your participation and commitment to this project. Have a blessed evening and see you tomorrow.

FG: Thank you sir, see you tomorrow!

Lesson 2: Stimulated recall interview

Topic Refraction of light

R: Good afternoon everybody!

FG: Good afternoon Mr Mutikisha!

R: How are you?

FG: We are fine Sir! And how are you sir?

R: Vey fine.

R: Today we are going to watch the video presentation for lesson 2. The purpose of watching this video is for me to have opportunity to ask you some questions based on what had happened during the lesson. I would like you to feel free to answer questions that will be posed to you while watching the video.

L: Ok sir!

R: Explain what you mean when you said your image in a bowl of water is upside down.

L; Ok, Yes! I see my face and my image were facing each other; my body is upright but my image in water facing downward.

R: You compared the surface of water with that of the mirror. Why and how do you relate them?

L: The surface of water is very shiny and smooth, ok, that image is not a real object under water, if you go into water, you cannot touch it there, just like that of the mirror.

R: You said you see two coins under water, and then just shake on your head. What do you mean?

L: Sir! Aaye! I was just confused; I do not know which one is the image or object.

R: Why did you put a ruler in water if the teacher did tell you to do so in the instructions?

L: Ok, I just wanted to show this one (pointing to another learner) that the ruler look bend just like refracted light.

R: This is the end of our video presentation and interview. I hope you have really enjoyed it. Thank you for your participation and cooperation.

FG: Thank you sir!

R: Same to you my dearest learners and have a blessed evening.

Lesson 3: Stimulated recall interview

R: Good afternoon learners!

FG: Good afternoon sir!

R: How are you?

FG: We are fine sir.

R: That's great, I thank you.

R: Ok, today is our last day for watching video-taped lesson presentation and interview. We are going to watch a video presentation for our last lesson and as usual I will ask you questions based on what was not clear to me during the lesson.

R: When the lamp was raised little higher while the pencil and the mirror remained fixed. You predicted that the pencil would also move up. Why did you think about this?

L: No, I thought the image follow the movement of light, but I was wrong sir.

R: When the lamp was raised little higher while the pencil and the mirror remained fixed. You predicted that the height of the image of the pencil in the mirror become taller. Why did you think about this?

L: Sir! I am not sure, but during the sunrise and sunset, shadows of trees become longer.

R: How did you relate shadow to the image in the mirror?

L: Sir, I think shadows and image are all caused by light. Oooh, but is confusing me.

R: This is the end of our video presentation and focus group interview. I hope we had a very wonderful engagement throughout these videos watching.

APPENDIX K: Pre-test question paper

PRE-TEST INSTRUMENT IN THE TOPIC LIGHT INSTRUCTIONS

Please write your surname, name and class in the spaces provided.

This is a pre test which is meant to identify your experiences, sense making and prior knowledge in the topic of light.

Your performance in this test will not affect your academic results in any way.

The test contains a total of 15 questions. Please answer ALL the questions.

For multiple choice questions, please circle the correct option.

Please make sure this test is an individual work.

The results of the test will be strictly confidential and will only be used for the purpose of research.

SURNAME:

NAME:

CLASS:

QUESTION 1

1.1 Three coloured (white, blue and black) papers are placed on top of the table in a dark room. Learners are asked to enter the room. Which one of the coloured papers can be easily seen by the learners?

(A) Blue paper

(B) White paper

(C) Black paper

(D) None of the above

1.2. How sure are you of your answer?

A. Certain B. Almost certain C. Almost a guess D. A totally-guessed answer

1.3. Explain the choice of your answer 1.1

1.4. How sure are you of your reason?

- A) Certain B) Almost certain C) Almost a guess D) A totally-guessed reason

QUESTION 2

2.1. As shown in the figure, what is the phenomenon that generates an inverted image of the Zebras drinking water in the lake?

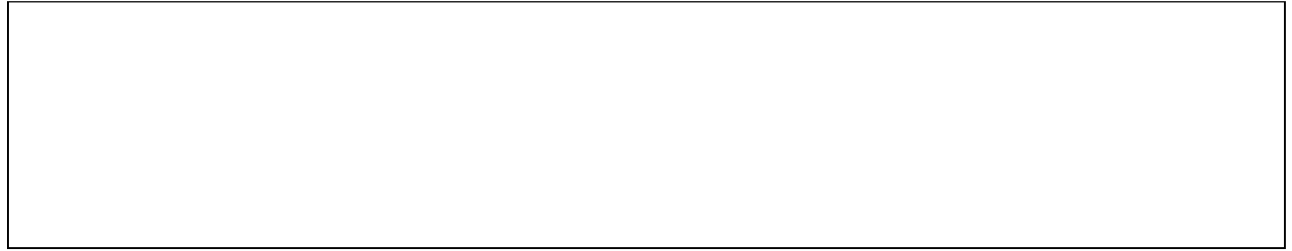
- A) Reflection B) Refraction C) Dispersion D) Diffraction



2.2. How sure are you of your answer?

- Certain B) Almost certain C) Almost a guess D) A totally-guessed answer

2.3. Explain your answer in 2.1



2.3. How sure are you of your reason?

- A) Certain B) Almost certain C) Almost a guess D) A totally-guessed reason

QUESTION 3

At midnight, Angula 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?

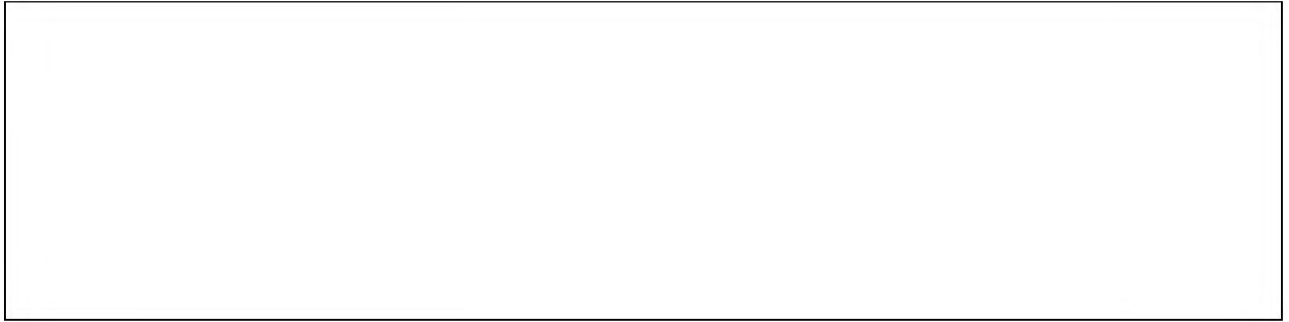
3.1. Please choose.

- (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) Non of the above

3.2. How sure are you of your answer?

- A) Certain B) Almost certain C) Almost a guess D) A totally-guessed answer

3.3. Explain your answer in 3.1

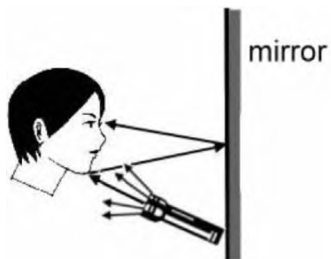


3.4. How sure are you of your reason?

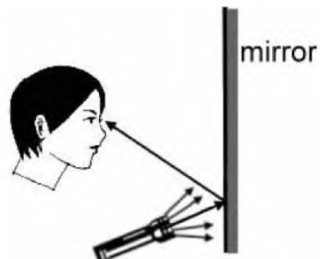
- A) Certain B) Almost certain C) Almost a guess D) A totally-guessed reason

3.5. Which of the following ray diagrams can best explain your answer in (3.1)?

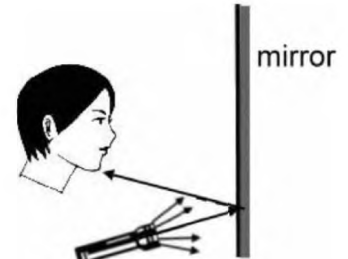
(A)



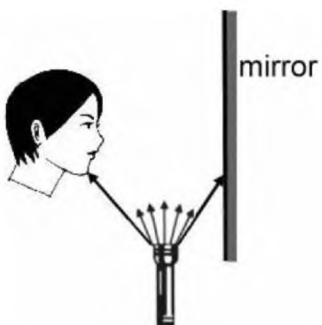
(B)



(C)



(D)



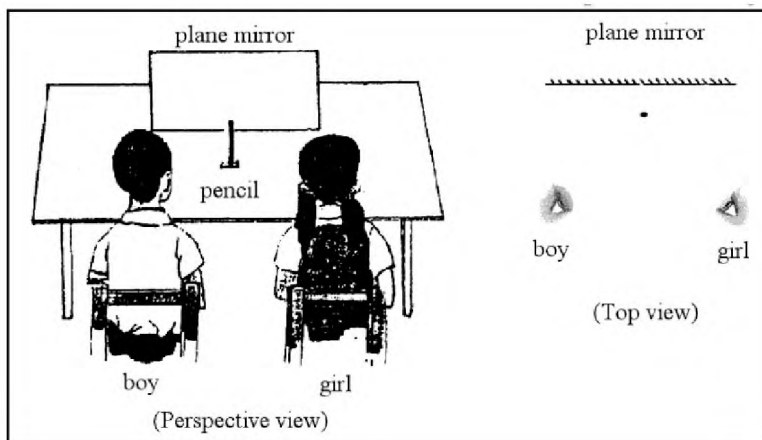
3.6. How sure are you of your ray diagram?

- A) Certain B) Almost certain C) Almost a guess D) A totally-guessed diagram

3.7. Explain the your answer in 3.5

QUESTION 4

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



4.1. Which of the following statements is correct? (Please choose)

- (A) The locations of the image seen by both students are the same.
(B) The location of the image seen by the Tangi is on the right side of that seen by Nangula.
(C) The location of the image seen by the Tangi is on the left side of that seen by the Nangula.

(D) None of the above

4.2. How sure are you of your answer?

A) Certain B) Almost certain C) Almost a guess D) A totally-guessed answer

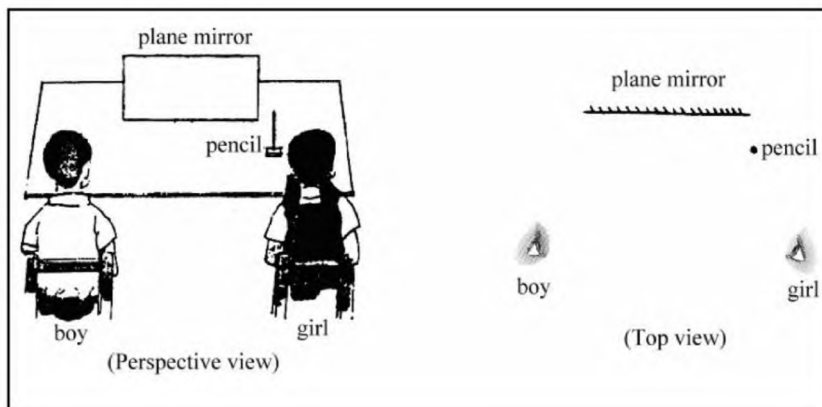
4.3. Explain for your answer in 4.1.

4.4. How sure are you of your reason?

A) Certain B) Almost certain C) Almost a guess D) A totally-guessed reason

QUESTION 5

Regarding the above problem: If the pencil is moved to the right until it reaches the edge of the mirror, and if both students move farther 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 or not?



5.1. Please choose:

- (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) None of the above

5.2. How sure are you of your answer?

- A) Certain B) Almost certain C) Almost a guess D) A totally-guessed answer

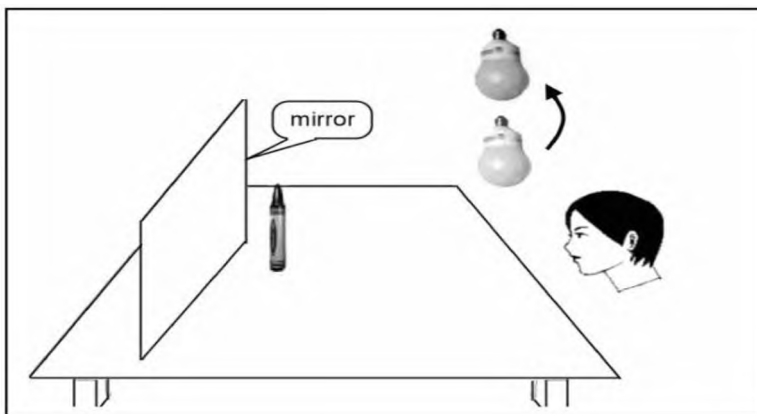
5.3. Explain your answer in 5.1.

5.4. How sure are you of your reason?

- A) Certain B) Almost certain C) Almost a guess D) A totally-guessed reason

QUESTION 6

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.



6.1. 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 choose.

- (A) It will move up.
(B) It will move down.
(C) It will stay in the same place.
(D) None of the above.

6.2. How sure are you of your answer?

- A) Certain B) Almost certain C) Almost a guess D) A totally-guessed answer

6.3. Explain your answer in 6.1.

6.4. How sure are you of your reason?

- A) Certain B) Almost certain C) Almost a guess D) A totally-guessed reason

QUESTION 7

Regarding above question: If the lamp is raised a little higher, what will happen to the height of the image of the pencil as seen by the observer?

7.1. Please choose:

- (A) The image will become longer.
(B) The image will become shorter.
(C) The image will remain unchanged.
(D) None of the above.

7.2. How sure are you of your answer?

- A) Certain B) Almost certain C) Almost a guess D) A totally-guessed answer

7.3. Explain your answer in 7.1.

7.4. How sure are you of your reason?

- A) Certain B) Almost certain C) Almost a guess D) A totally-guessed reason

QUESTION 8

Regarding the above question: The lamp stays fixed. The pencil is moved a little further from the mirror. What will happen to the height of the image of the pencil as seen by the observer?

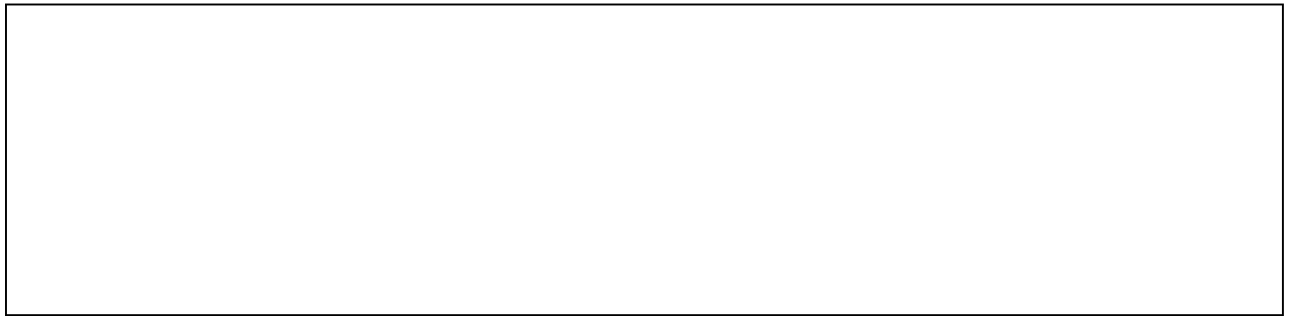
8.1. Please choose:

- (A) The image will become longer.
- (B) The image will become shorter.
- (C) The image will remain unchanged.
- (D) None of the above.

8.2. How sure are you of your answer?

- A) Certain B) Almost certain C) Almost a guess D) A totally-guessed answer

8.3. Explain your answer for 8.1.

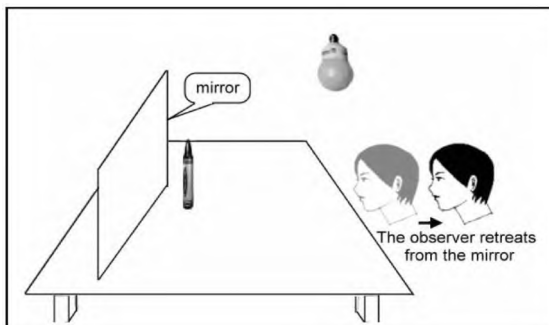


8.4. How sure are you of your reason?

- A) Certain B) Almost certain C) Almost a guess D) A totally-guessed reason

QUESTION 9

Regarding 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 as seen by the observer?



9.1. Please check:

- (A) It will retreat from the mirror.
(B) It will approach the mirror.
(C) It will stay at the same location.
(D) None of the above.

9.2. How sure are you of your answer?

- A) Certain B) Almost certain C) Almost a guess D) A totally-guessed answer

9.3. Explain your answer in 9.1.

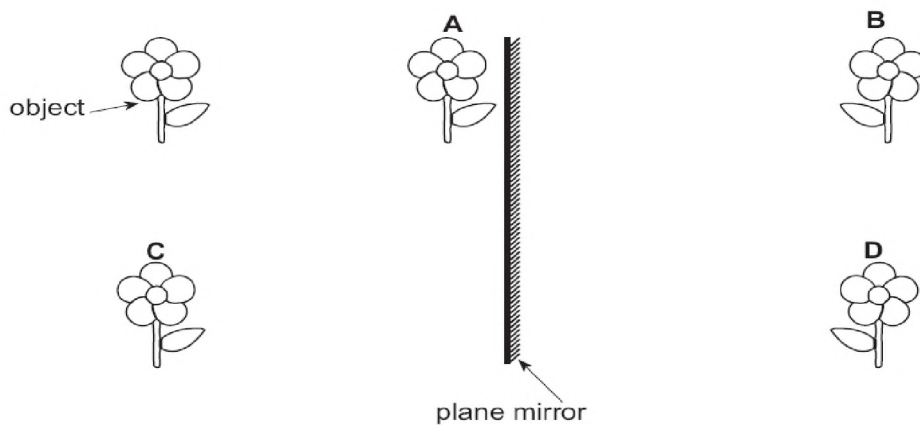
9.4. How sure are you of your reason?

- A) Certain B) Almost certain C) Almost a guess D) A totally-guessed reason

QUESTION 10

An object forms an image in the plane mirror.

10.1. Which is the correct position of the object's image?



How sure are you of your answer?

- A) Certain B) Almost certain C) Almost a guess D) A totally-guessed answer

Explain your answer for 10.1.

How sure are you of your reason?

- A) Certain B) Almost certain C) Almost a guess D) A totally-guessed reason

Question 11

11.1. Which of the following objects are able to reflect the light rays?

- A) A wooden table
B) A silver spoon
C) A mirror
D) All the above

11.2. How sure are you of your answer?

- A) Certain B) Almost certain C) Almost a guess D) A totally-guessed answer

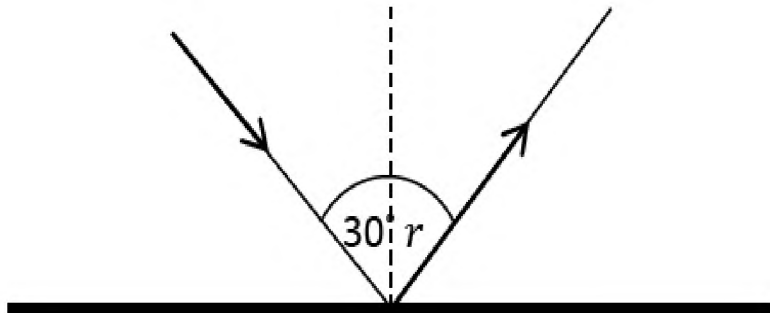
11.3. Explain your answer in 11.1.

11.4. How sure are you of your reason?

- A) Certain B) Almost certain C) Almost a guess D) A totally-guessed reason

QUESTION 12

The diagram below shows reflection on a plane mirror.



12.1. What is the value of the angle of reflection?

- A) 15 degree
- B) 30 degree
- C) 60 degree
- D) 180 degree

12.2. How sure are you of your answer?

- A) Certain
- B) Almost certain
- C) Almost a guess
- D) A totally-guessed answer

12.3. Explain your answer in 12.1.

12.4. How sure are you of your reason?

- A) Certain
- B) Almost certain
- C) Almost a guess
- D) A totally-guessed reason

QUESTION 13

When light travels from air into glass its speed changes.

13.1. What is this effect called?

- A) Diffraction
- B) Dispersion
- C) Reflection
- D) Refraction

13.2. How sure are you of your answer?

- A) Certain
- B) Almost certain
- C) Almost a guess
- D) A totally-guessed answer

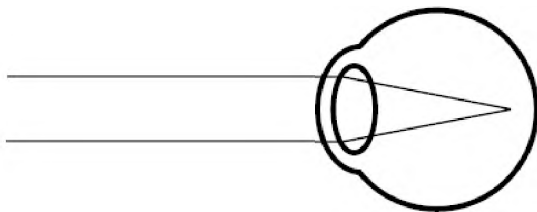
13.3. Explain your answer for 13.1.

13.4. How sure are you of your reason?

- A) Certain
- B) Almost certain
- C) Almost a guess
- D) A totally-guessed reason

QUESTION 14

The diagram shows an eye ball of a person who cannot see distant objects clearly.



14.1. Which line in the table states the eye defect and the lens used to correct it?

	defect	Lens
A	long sightedness	convex
B	long sightedness	concave
C	short sightedness	concave
D	short sightedness	convex

14.2. How sure are you of your answer?

14.3. Explain your answer in 14.1.

14.4. How sure are you of your reason?

A) Certain B) Almost certain C) Almost a guess D) A totally-guessed reason

QUESTION 15

Light travels from glass into a vacuum.

15.1. Which one of the statements is true?

- A) Light does not travel through the vacuum.
- B) The light will travel faster in the vacuum.
- C) The light will travel more slowly in the vacuum than in the glass
- D) The light will continue at the same speed than in the glass

15.2. How sure are you of your answer?

A) Certain B) Almost certain C) Almost a guess D) A totally-guessed answer

15.3. Explain your answer in 13.1.

15.4. How sure are you of your reason?

- A) Certain B) Almost certain C) Almost a guess D) A totally-guessed reason

***** Thank you for your co-operation *****

*This pre test is adopted from the following source: **John, 2014***

