UNIVERSITY OF EDUCATION, WINNEBA

EFFECTS OF PRACTICAL ACTIVITY METHOD ON SCIENCE PRACTICAL PROCESS SKILLS OF SENIOR HIGH SCHOOL STUDENTS

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DECLARATION

STUDENT'S DECLARATION

I, Michael Anto, declare that this thesis, with the exceptions of quotations and references contained in published work which have been identified and duly acknowledged, is entirely my own my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

Signature:……………………………………

Date:……………………………………….…

SUPERVISOR'S DECLARATION

I hereby declare that by the preparation and presentation of this work supervised in accordance with the guidelines of supervision of thesis laid down by the University of Education, Winneba.

Mawuadem Koku Amedeker (Supervisor)

Signature:……………………………………

Date:……………………………………….…

DEDICATION

I dedicate this work to my beloved family (the Abalimah, Montor, Anto and Quaye family of Ejura and Apam).

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ABSTRACT

The purpose of this study was to assess physics students' practical science process skills. In this study, practical action research was adopted as the research design that guided the study. In this study, the target population comprised all general science students studying physics at Apam Senior High School in the Central Region, Ghana. The study involved a total of 45 Senior High School Form Two physics students in Apam Senior High School in the central region of Ghana. The research instruments used to collect data for this study was a questionnaire and teaching intervention. Pre-intervention and post-intervention practical tests were designed to determine students' level of acquisition of science process skills before and after the intervention. This study also employed a questionnaire to gather additional information from the students on the impact of the intervention. Statistical Package for Social Sciences (SPSS) version 21 was used in analysing pre-test scores, post-test scores obtained from pre-intervention and post-intervention respectively. Data collected from the questionnaire was also analysed using SPSS. It was found that a significant number of students (about 40%) were unable to accurately measure angles of incidence (i) and angles of reflection (r) using the protractor and about 60% were able to measure. Again, the study revealed that a significant percentage of the students lack sufficient skill of presenting data. Specifically, 17(37.8%) of the students could not correctly plot points on a graph and majority of the students could not compute the slope of a graph. The positive impact of the intervention was attributed to the teaching method (demonstration by the researcher and team work among students) employed. Based on the findings, it was recommended that Science practical process skills such as measuring, making inferences, data presentation and interpretation should be taught in the physics classroom. This will enhance science students' efficiency in understanding science through experimentation. Again, Apam senior high school physics teachers should teach science practical process skills via demonstrations and also allow for student-students interactive learning through team work for improvement of students' performance in physics.

CHAPTER ONE

INTRODUCTION

1.0 Overview

This study seeks to assess Senior High School students' science process skills in optics. Process skills are effective for the study of concepts in science of which physics is the main focus for this study. Optics is one of the topics in physics which is embedded with a lot of everyday applications of process skills. While various studies have recognized the importance of science process skills, little attention has been paid on how to assess students' process skills in optics which is very important in the science classroom. Since assessment of science process science skills in optics involves hands-on and minds-on activities where students are given opportunities to interact with their immediate environment, this study will employ the constructivist theory of learning which posits that students can construct their own knowledge when the needed environment is created (Rob & Rob, 2018).

1.1. Background to the Study

Considering the importance of science education in the development of a given nation, teachers in science must play a key role. It is clear that with the changing trends in education in terms of teaching and learning as indicated by the curriculum of Ghana, Ministry of Education (2010), science teachers are moving from the traditional role they played in the past; here the emphasis were on content knowledge and understanding. Currently, in this twenty first century, the focus is on skills development and developing the students' understanding of the nature of science. There is the need for a supportive environment for effective teaching and learning of science in Ghana. According to Boakye (2010), teaching and learning of science is challenging in Ghana due to some factors, which include: resources required, human as well as material resources; and lack of effective practical work ethics. It must be stated that the practical work done in science in most Ghanaian Senior High Schools is often “not interesting" for students, and neither is it effective in improving learning (Cornah, 2016). Students are made to follow a list of instructions, and investigations are carried out for examinable course work only.

The objectives of most Ghanaian senior high schools are to complete the practical work for the examination rather than thinking critically about why exactly students are carrying out investigations. According to Ampiah (2004), WAEC Chief Examiners for physics, chemistry and biology over the years reported students' weaknesses in science practical examinations. If used well, practical work will generate interest in pupils and students as well as curiosity in a given topic. In science we strive for pupils and students to start asking 'what if' to be actively involved in the learning process not just the 'hands-on' but have a 'minds-on' (Johnson, 2001). If students are thinking, discussing and doing, then their minds will be actively involved. Science is not and should not be just about learning the facts; it is about acquisition of process skills; learning to observe, measure, hypothesize, predict and evaluate the findings (Aboagye, 2009). In addition, science is about communication, teamwork and self-discipline. When science is put in a real context, in a way which is very relevant to them, students will often see the purpose and engage more effectively with the learning. The management of practical lessons from a teacher's point of view is crucial for learning and safety.

Instructional strategies and curriculum sequencing aimed at teaching science process skills have received considerable attention in science education (Ampiah, 2004; Johnson, 2001). Laboratory instruction has long had a significant role in science education and literature pointing out the gains of students from engaging in science laboratory activities (Sunal, Sunal, Sunberg & Wright, 2008). It is therefore for physics teachers to pay heed to laboratory activities for these benefits to be realised fully.

1.2. Statement of the Problem

Elective physics is one of the cornerstones of the science subjects taught at the senior high school levels in the Ghanaian educational system. However, students do not show satisfactory competencies in the development of science practical process skills, such as designing experiments, analyzing data and drawing conclusions during laboratory or practical sessions (Johnson, 2017) in Physics. In spite of its importance as a fundamental course to technology and engineering, it is less attractive to science students at the tertiary level (Aboagye, 2009).

It is important to train students to be equipped with science practical process skills and scientific thinking. According to the syllabus provided for senior high schools by CRDD of Ministry of Education (2010), elective physics is supposed to be learnt both theoretically and practically (laboratory activities; hands-on and minds on). It was observed that some physics teachers would rather wait until the students get to the final year before introducing the students to the laboratory practical work knowing very well that practical should be done alongside the theory. This means that students would have developed science practical process skills for meaningful learning ahead of time before reaching their final year (Cornah, 2016).

It appears research has not been able to show how science practical process skills can be assessed effectively in order to yield the appropriate results. This current study therefore will seek to assess the proficiency levels (measuring, inferring and data presentation) of science practical process skills in physics at the senior high school level and how practical activity as an intervention would affect these process skills.

1.3. Purpose of the Study

The purpose of the study was to assess the proficiency levels of senior high school Form 2 science students (i.e., those who offer physics, chemistry, biology and mathematics as electives) in physics practical. Specifically, the study aimed at assessing the proficiency levels of students' process skills in measuring, inferring and data presentation as far as physics practical work in concerned.

1.4. Research Objectives

The research was guided by the following objectives:

i. to assess students' inappropriate and appropriate responses for measuring, inferring and data presentation in reflection.

ii. to assess students' inappropriate and appropriate responses for measuring, inferring and data presentation in refraction.

iii. to assess the impact of a teaching intervention on students' ability to develop science practical process skills of measuring, inferring and data presentation.

iv. to assess the performance levels of physics students engaged in science practical process skills of measuring, inferring and data presentation in reflection and refraction after the intervention.

1.5. Research Questions

The following were research questions of the study.

1. What are students' appropriate and inappropriate responses for measuring, inferring and data presentation in reflection?

2. What are students' appropriate and inappropriate responses on refraction tasks which involve measuring, data presentation and inferring?
3. What impact has the teaching intervention had on students' ability to acquire science practical process skills of measuring, inferring and data presentation?
4. What are the performances of physics students engaged in science practical process skills of measuring, inferring and data presentation in reflection and refraction?

1.6. Significance of the study

Firstly, the tasks that was developed for this study would be useful to senior high school physics teachers to administer to their students to create interest in practical work due to its short periods of completion for each task. Secondly, the findings of this study will likely bring to light some of the causes why elective physics students are not performing so well in the WASSCE physics practical examinations. Again, the outcome of this study would highlight some students' weaknesses as well as strengthens in carrying out laboratory work under examination conditions.

1.7. Delimitations of the Study

Though there are other topics in physics at the SHS level, the study focused on only optics: tasks on reflection and refraction as provided in the syllabus for Elective physics (Ministry of Education, 2010). Only Form Two students offering physics, chemistry, biology and mathematics as electives (General Science Programme) were used in this study, since they would have done reflection and refraction in form one and two.

Again, this study was confined to only three aspects of science practical process skills, which are measuring, inferring and data presentation.

1.8. Limitations of the Study

Extraneous variables like students learning experience, ability, age, maturation, exposure as well as previous learning were beyond the control of the researcher. These variables could influence students' science practical process skills of measuring, inferring and data presentation of concepts in optics and so may lack internal validity. Timeframe being relatively short, and for financial restrains, the research was unable to cover more than a region in Ghana.

1.9 Organization of the Remainder of the Study

The entire work was organized into five chapters. Chapter Two dealt with the review of relevant literature based on the research questions outlined in the study. It also entailed the theoretical and conceptual framework underpinning the study.

Chapter Three was centered on the methodology employed in this study. It described the research design, study area, population, sample and sampling techniques, data sources, research instruments, dating collection procedure, data management and data analysis as well as ethical issues.

Chapter four was used to present the results of the study as well as discussions on the key findings. Finally, Chapter Five gave the summary of the study, and made conclusions on the key findings of the study. It also outlined the recommendations and suggestions for further studies based on the findings of the study. These chapters were logically presented to provide insight into issues raised in the chapters.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview

This chapter reviews relevant related literature that provides support for the study. The literature review is divided into two main headings namely; theoretical framework and empirical review. Under the theoretical framework, the constructivists view of teaching and learning was discussed. Empirical review comprises a survey of related and relevant studies carried by previous researchers. Empirical review was done under headings such as; science process skills, relevant of science practical and its impact on students' achievement. The role of laboratory practical work in the development of science process skills as well as students' knowledge and understanding of the concept of optics were also reviewed.

2.1. Theoretical Framework

This study was supported by the constructivists theory which seeks to posit that learners construct their own knowledge in a learning environment which was addressed in detail.

2.1.1 Constructivism

Constructivism is an epistemology (a theory of the nature of knowledge) based on the work of variety of philosophers, psychologists, and educators. Amongst them are: Immanuel Kant, Lev Vygotsky, John Dewey, Jean Piaget, Jerome Bruner and Noward Gardner. Constructivist theorists see the learning process as a result of experience (Ertmer & Newby, 2013). People acquire knowledge through doing and experiencing things. In constructivism, the goal of learning is to construct knowledge. (Merriam, Caffarella & Baumgartner, 2007). Constructivism holds that students create new knowledge as a result of the interaction of their existing knowledge, beliefs and values with new ideas, problems, and that knowledge is not universal, objective, but is constructed or co-constructed by learners (Glickman, Gordon & Ross-Gordon, 2004). Constructivism proposes that knowledge is actively built up by the learner and not transmitted directly from one person (e.g. teacher) to another (e.g. learner). Constructivism as a teaching method allows the learners to do something and at the same time to construct new meaning (Merriam et al., 2007). A constructivist classroom is characterized by the high percentage of the time spent on student-centered activities and dominated by collaborative learning style. As per constructivist principles, learning is a process in which individuals construct knowledge. Communication, negotiation, cooperation, reflection, discussion and reciprocity are qualities of Constructivist approach (Karala & Reisoglu, 2009). Applying Constructivism theory in the classroom can be useful to students in enabling them pursue personal interests and purposes, use and develop his or her abilities, build on his or her prior knowledge and experiences and most importantly develop life- long learning (Christie, 2005).

There is no one constructivist theory of learning, but most constructivists share two main ideas: learners are active in constructing their own knowledge and social interactions are important in knowledge construction (Bruning, Schraw, Norby, & Ronming, 2004). According to Driscoll (2005), all constructivist theories assume that knowing develops as learners try to make sense of their experiences. Learners therefore are not empty vessels wanting to be filled but rather active organisms seeking meaning. These learners construct mental models or schemes and continue to revise them to make better sense of their experiences. Constructivists share similar goals for learning. They emphasize knowledge use rather than the storing of inert facts, concepts and skills. One way to organize constructivist views is to talk about two forms of constructivism: psychological (Individual) and social construction (Woolfolk & Margetts, 2012)

In general, psychological constructivists are concerned with how individuals build up certain elements of their cognitive or emotional apparatus. These constructivists are interested in individual knowledge, beliefs, self-concept, or identity, so they are sometimes called individual or cognitive constructivists; they all focus on the inner psychological life of people (Woolfolk & Margetts, 2012). Piaget’s psychological (cognitive) constructivist perspective is less concerned with “correct" representations and more interested in meaning as constructed by the individual. Piaget’s special concern was with logic and the construction of universal knowledge that cannot be learned directly from the environment (knowledge such as conservation or reversibility) (Miller, 2004). However, some educational and developmental psychologists have referred to Piaget’s kind of constructivism as “first wave constructivism” or “solo” constructivism, with its emphasis on individual meaning-making (Paris, Byrnes, & Paris, 2001).

On the other hand, social constructionists do not focus on individual learning. Their concern is how public knowledge in discipline such as science, math, economics or history is constructed (Woolfolk & Margetts, 2012). Vygotsky believed that social interactions (particularly in a broad range of activities with others), cultural tools and activities shape individual development and learning. Putting learning in social and cultural context is “second wave constructivism” (Paris, Brynes, & Paris, 2001). Many constructivists share Vygotsky’s belief that higher mental process develops through social negotiation and interaction (Woolfolk & Margetts, 2012). One way of integrating individual and social constructivism is to think of knowledge as individually constructed and socially mediated (Windschtl, 2002). Figure 1 below seeks to conceptualise the constructivists theory to suit this study as learner were engaged to interact with the real world practical learning as well as interact with their peers.

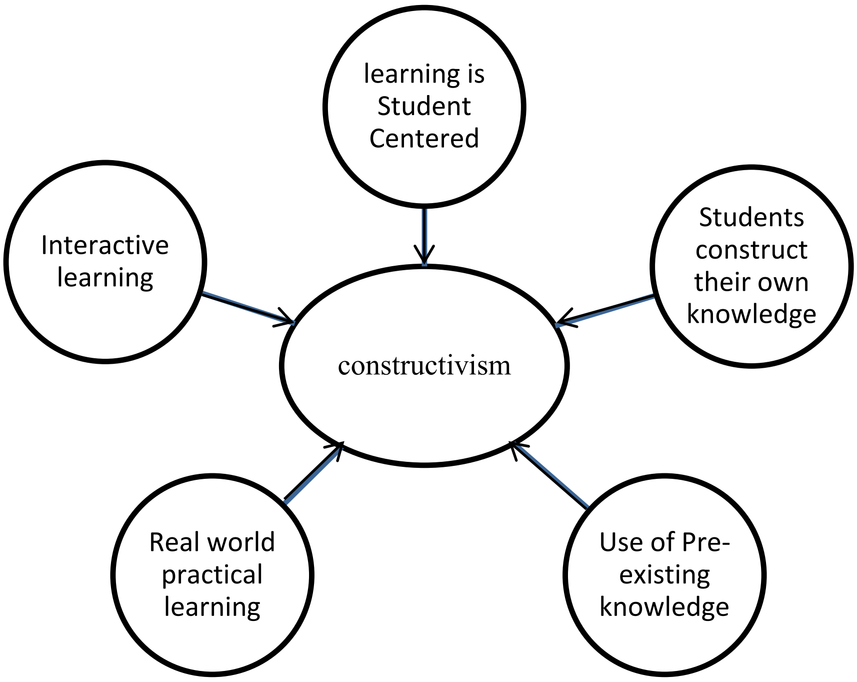

Figure 1: Theoretical Framework Involving Constructivism

2.2. Empirical Review

An extensive empirical review on science practical process skills supported and necessitated the study has been elaborated below.

***2.2.1* Laboratory Practical Work Versus Development of Science Process Skills**

Practical work to refer to any teaching and learning activity which gives students the opportunity to observe or manipulate the objects and materials in relation to the concept they are studying (Millar, 2015). The significant role laboratory work plays in science education cannot be underestimated (Hofstein & Mamlok-Naaman, 2007). According to Sotiriou, Bybee and Bogner (2017), the conduct of practical work is aimed at improving students' understanding, developing their skills in solving problems and understanding the nature of science, by replicating the actions of scientists. In the educational process, laboratories can be used to develop scientific notations and create models to test hypotheses. Laboratory work also helps in understanding the difference between observation and presentation of data (Shana &

Abulibdeh, 2020). A number studies conducted in the past have laid emphasis on the numerous merits of practical work in science education. The development of laboratory skills, scientific knowledge, as well as understanding science concepts and theories are a few of these merits (Fadzil & Saat, 2013; Schwichow, Zimmerman, Croker & Härtig, 2016). Science laboratory practical activities are expected to equip students with basic and integrated science process skills since science process skills are a part of laboratory activities. Nwagbo and Chukelu (2011) also confirms the efficacy of practical activities in fostering students' acquisition of science process skills. Okam and Zakari (2017) are also of the opinion that to ensure students positive attitude and motivation for effective science learning, practical work could be useful. When students are motivated enough to develop positive attitude towards science learning, it could eventually result in better students' performance (Hinneh, 2017).

Science learning through laboratory activities and the development of science process skills are integrated activities. Etiubon and Udoh (2017) noted that science learning employs experiments using enriching learning materials to equip learners with appropriate knowledge, skills, attitudes and behaviours. The development of science process skills is a valid aim for science laboratory work (Akinbobola & Afolabi, 2010). In other words, science process skill cannot be separated from the practical activities because it plays a key role in learning (Keil, Haney & Zoffel, 2009). Hofstein and Lunetta (2004) proposed that there is much theoretical support for the value of laboratory work in helping students to understand science. On the basis of these two claims it would seem appropriate to require physics students to acquire competence in some basic science process skills. Science process skills provide pupils and students with ways of finding out about their world - by seeking and using evidence, by observation or investigation, by interpreting information, drawing conclusions and applying ideas to new problems (Zeidan & Jayosi, 2015). Given that the subject matter of science is the material world, it seems natural, and rather obvious that learning science should involve seeing, handling and manipulating real objects and materials, and that teaching science will involve acts of 'showing' as well as of 'telling' (Millar, 2004). The search for a more effective approach for the teaching and learning of science that will enhance the acquisition of process skills has persisted over the years. This is because, the acquisitions of science process skills are the bases for scientific inquiry and the development of intellectual skills and attitudes that are needed to learn.

Nwagbo and Chukelu (2011) carried out a study to investigate the effect of biology practical activities on secondary school students' process skill acquisition in Abuja Municipal Area Council. They employed the quasi-experimental; specifically, the Pre-test, Post-test, Non-Equivalent Control Group Design. The results revealed that practical activity method was more effective in fostering students' acquisition of science process skills than the lecture method (Nwagbo & Chukelu, 2011). In a current study, the effect of practical work on students' academic achievement, acquisition of scientific process skills and attitudes towards the study of selected topics in electricity was investigated. It was found that students' level of acquisition of the requisite scientific process skills was greatly enhanced during the previous practical lesson (Antwi, Sakyi-Hagan, Addo-Wuver, & Asare, 2021). When learner observe, explore and investigate, they gain knowledge about the content and they may also apply existing knowledge to help make sense of what they observe. According to Woodley (2009) and Kulshretta (2013), effective practical work can help students develop important skills in understanding the process of scientific investigation and can also develop students' grasp of concepts. Despite the important roles laboratory practical plays in helping students develop science process skills, there are challenges hindering the frequent organization of practical by science teachers. Kemper (2000) states that science teachers do not have time to do practical activities due to the overloaded curriculum. This phenomenon compels teachers to concentrate more on completing the syllabus than on the pedagogy of science teaching (Osborne & Collins, 2001; Koballa & Tippins, 2000). Similarly, Halai (2008) also mentioned the overloaded science curriculum as one of the commonly reported constraints in science education.

2.2.2 The Relevance of Practical Work and its Effect on Students' Academic Achievement

Etuibon and Udoh (2017) defined practical activities as an act of engaging in and equipping oneself with hands-on-skills. According to Lunetta, Hofstein, and Clough (2007), practical work is a learning experience in which students through interaction, observe and understand the natural world. Similar to the definition of Lunetta, Hofstein and Clough (2007), Millar (2004) is also of the view that practical work is an educative activity that entails students observing or manipulating an object or any other laboratory materials. SCORE (2009) and Achimugu (2014) also perceive practical work (fieldwork, laboratory works and experimental works) in science as a 'hands-on learning experience which prompts thinking about the world in which we live'. Over the years, many have argued that science cannot be meaningful to students without engaging them in practical experiences (Doosti, 2014; Hofstein & Mamlok-Naaman, 2007). Kallats (2001) sees practical works as a means to verify a science principle, or theory already known to the students; a means of determining the relationship between cause effect and a means of obtaining and learning scientific information. Science learning is described as one which is practical-oriented and requires practical activities in the laboratory. It requires broad-based experiences to widen students' knowledge in a world of abundance of choices and opportunities to give meaning to learning (Etuibon & Udoh, 2017). Ogunleye (2010) also hold a similar opinion about science and define it as an act of inquiry which includes empirical observation and experimentation and has become a tool for the technological development of nations. According to Okoye (2013), learning science practically develop students' scientific knowledge and are most effective when the learning objectives are clear and relatively few in number for any given task. The aims of studying science in senior high schools as spelt out in the West African Examinations Council (WAEC, 2014) syllabus include among others; understanding basic science concepts, acquisition of laboratory skills, awareness of linkage between science and industry/environment and everyday life in terms of benefits and hazards and acquiring skills of critical and logical thinking. This is aimed at preparing students to become productive individuals at the job place (Etiubon and Udoh, 2017). According to Tiberghien (2000), the purpose of practical work is to help students to link the abstract, theoretical ideas with real phenomenon. Some school of thought hold the view that science content knowledge cannot be effectively taught unless the learner is actively involved in the teaching-learning process. Practical work in the form of laboratory activities can be one of the tools through which the learner is made an active part of the learning process (Doosti, 2014).

There are several reports on the merits of practical work in the study of science. Lazarowita and Tamir (2006) are of the view that practical work provides students' the opportunities to perform various hand- on- activities to be able to discover scientific facts for themselves. They further indicated that science learning through practical activities enable students develop manipulative skills, attitude and interest that simplify science concepts as well as promote conceptual change among students. In congruence with the finding of Lazarowita and Tamir (2006), Scanlon, Morris, Terry and Cooper

(2002) believe that practical work has a significant role in enhancing the conceptual and procedural understanding of science students. The National Science Education Standards in the United States and other contemporary science education literature continue to suggest that school science laboratory activities have the potential as a medium for introducing students to central conceptual and procedural knowledge and skills in science (Bybee, 2000). In support of this argument, Hofstein and Lunetta (2003) stated that for more than a century, laboratory work activities have played a central and distinctive role in Physics education, suggesting long recognition of important role played by laboratory practical activities in the teaching-learning process of Physics. Practical work also creates and boosts students' motivation, interest and achievement. It creates opportunities for active teaching-learning in Physics (Okam & Zakari, 2017).

Effective practical works make difficult and abstract concepts real, remove misconceptions, ignite, increase and sustain students' interest in science (Etiubon and Udoh, 2017). Due to these reasons, most stakeholders will agree that practical work is an integral part of science education. However, the benefits of practical works will be attained if it is well organised and implemented in a coherent manner (Doosti, 2014). It is imperative therefore, to give effective interpretation of existing phenomena and to gain useful insight into science as life using appropriate practical activities (Njelita, 2008). It is believed that effective practical activities build a bridge between hands-on and minds-on activities (Woodley, 2009). Millar and Abrahams (2009) suggest that the minds-on aspects of practical work must be increased in order to make it more effective in developing students understanding of scientific ideas. Practical work can make the learning surrounding exceptional which indirectly help students understand the real world, construct their knowledge, enhance logical, inquiry and psychomotor skills

(Millar, 2004). Practical activities create an experience where students can widen the possibility of constructivist learning (Umar, Ubramaniam, & Ukherjee, 2005).

Aside the numerous benefits of practical works in science, there are also evidences of the positive effects of practical work on students' academic achievement. Roberts (2008) found that through experimentation, students are able to attain a deeper level of understanding of concepts by finding things out for themselves. A deeper understanding of concepts will eventually result in improved academic achievement among students. Practical work has also been found to promote students’ positive attitudes and enhance motivation for effective learning of science (Okam & Zakari, 2017). Consequently, a positive attitude toward the importance of practical work meaningfully affects students’ achievement in science (Hinneh, 2017). Antwi, Sakyi-Hagan, Addo-Wuver and Asare (2021) conducted a study to investigate the effect of practical work on students' academic achievement, acquisition of scientific process, skills and attitudes towards the study of selected topics in electricity. Fifty (50) Form Two Physics students from a Senior High Technical School in the Kwaebibirem Municipal of the Eastern Region of Ghana participated in the study. Instruments used to collect data included a student learning evaluation form, questionnaire and pre-and-post-intervention tests. The findings indicated that the students' academic performances were enhanced as a result of the practical activities students were engaged in. The study recommended that Physics teachers should adopt practical work as a teaching technique and as well be encouraged to teach concepts alongside with practical activities. A similar study (quasi-experimental) was conducted by Shana and Abulibdeh (2020) to evaluate the overall effect of practical work on students’ academic attainment in science. Participants were selected from tenth grade students (chemistry and biology) and eleventh grade students (chemistry), then divided into groups. The control groups were taught using traditional methods of teaching science, while the same content was given to the experimental groups using intensive practical work. Pre and post-tests were given to all groups. The mean score comparison revealed a significant difference in the attainment scores of the experimental over the control groups. It is thus recommended that students be given ample opportunity to be engaged in practical lessons in secondary schools. Another study whose findings provide evidence of the crucial role practical work play in the academic performance is that of Etiubon and Udoh (2017). They conducted a study to investigate the effects of practical activities and manual on science students' academic performance on solubility in Uruan Local Education Authority of Akwa Ibom State. The study adopted pre-test, post-test non randomized quasi experimental design. The findings of the study that students performed significantly better when taught the concept of solubility with practical activities and with practical manual. It therefore means that, effective and quality instructional delivery in the classroom and beyond depends to a large extent on the utilization of instructional materials for practical activities to enhance students' academic performance (Etiubon & Udoh, 2017). Despite the numerous reports of the benefits of practical work by previous studies, findings of some studies pointed out some contrasting view with regards to laboratory-based teaching. Abrahams and Millar (2008) mentioned that laboratory-based teaching is an inefficient teaching method and cannot represent scientific inquiry properly, rather this should be taught through direct lecturing. Teaching practical or lab work does not necessarily mean a better education; instead the efforts to improve the quality of lab work. Improvement of "practical and enquiry skills" might be the right steps toward effective science education (Dillon, 2008).

2.2.3 Science Process Skills

Science is defined as a systematic process of seeking for knowledge about nature through systematic observation and experimentation (Anaekwe, Nzelum, Olisakwe and Okpala, 2010). The act of observing and experimenting requires essential skills known as science process skills. Science process skills (SPSs) are highly accepted set of skills needed by scientist. In other words, Science process skills are skills used by scientists in solving scientific problems (Monhardt & Monhardt, 2006). Anaekwe, Nzelum, Olisakwe and Okpala (2010) also referred to science process skills basic tools or techniques which are employed by scientist in the study of science. According to Hill (2011), science process skills as the underlying skills and premises which govern the scientific method.

It could be inferred from the above definitions that the place of science process skills cannot be underestimated because of the significant role it plays in the study of science. Evidences from literature has shown that the knowledge of science process skills is central to the development of scientific culture by learners and for the development of the society in general (Zeidan & Jayosi, 2015). Science process skills knowledge is essential for the effective learning of science at all levels. Through scientific method, scientists use process skills to test hypothesis and obtain evidences. The effective use of the Science process skills are essential practical skills to develop scientific knowledge (Ongowo & Indoshi, 2013) and play an important role in students' ability to learn science by doing and experiencing it directly (Erkol & Ugulu, 2013). According to Alkan (2016), the application of science process skills enables individuals to actively participate and take responsibility for learning various methods of scientific research and applying scientific learning to improve learning methods in the long term. Students are empowered to explore and address important issues and problems around them using SPSs (Kazeni, 2005; Ongowo & Indoshi, 2013). Science process skills are a necessary tool to produce and use scientific information, to perform scientific research and solve problems. Millar and Driver (2008) reiterated the crucial role of science process skills by stating that concepts and principles of science can only be obtained through a series of scientific processes, such as observing, classifying, describing, communicating, drawing conclusions, making operational definitions, formulating hypotheses, controlling variables, interpreting data, and experimenting. Vitti and Torres (2006) also indicated that, science process skills such as measuring, sorting or classifying, concluding, guessing/predicting, experimenting, and observing are valuable in situations where critical thinking is needed. And most importantly, Olufunminiyi and Afolabi (2010) indicated that science process skills enable students to be probed to creativity, problem solving, reflective thinking, originality and invention, which are vital ingredients for the development of science and technology of any nation. Science process skills are obtained through experience and skill development through practice (Faruk & Lu, 2012). The SPSs cannot be separated in practice to understanding the concepts involved in learning and applying science (Karamustafaoğlu, 2011).

A number of studied conducted in the past have laid much and further emphasis on the relevance of science process skills in the study science. Listed below are some findings and conclusions made by various researchers. The knowledge of science process skills:

i. helps students to develop formal thinking ability and thus appreciate the relevance of science in everyday life (Chinyere, Amba & Obogo, 2020)

ii. are the building-blocks of critical thinking and inquiry in science (Vitti & Torres, 2006).

iii. Is essential asset to bring out and use scientific evidence, to carry out scientific exploration and to unravel problems (Huppert, Lomask & Lazarorcitz, 2002)

iv. enhances students' creative thinking skills of students (Lee & Lee, 2002)

v. are used to gather information about nature. Science process skills are thinking skills used to process information, solve problems and form conclusions (Özgelen, 2012).

vi. give students meaningful learning experiences because they help students to achieve high-level thinking (Tilakaratnea & Ekanayakeb, 2017).

In conclusion, the acquisition of SPSs have a profound impact on the success of students in science classes on higher education (Tilakaratnea & Ekanayakeb, 2017). Ongowo and Indoshi (2013) are of the view that the effective use of SPSs can enhance students' content knowledge acquisition with deeper understanding. Dirks and Cunningham (2006) concluded in their studies that Science process skills need to be utilized by teachers to teach the science facts and concepts effectively. This is because science is not only knowledge but also a systematic way to understand the environment (Turiman, Omar, Daud & Osman, 2012). It's important to equip the teachers with the scientific process skill, especially for novice biology teacher candidates. The SPSs are important for them so they can teach their students to master not only the concepts but also how to get that knowledge (Susanti, Anwar & Ermayanti, 2018).

Science process skills can be grouped under two main categories: basic science process skills (simple skills) and integrated science process skills (complex, higher-order) (Gurses, Çetinkaya, Dogar & Sahin, 2015; Delen & Kesercioğlu, 2012; Ozgelen, 2012; Chiappetta & Koballa, 2002). In a similar way**,** Errabo and Prudente (2018) referred to science process skills as Investigative skills which comprises of the basic Science process skills and integrated process skills. Ango (2002) is of the view that both basic and integrated scientific skills are important in any scientific investigation such as conducting projects and carrying out experiments. Appropriate selections of science process skills can be taught and studied in the early years of primary school.

2.2.4. Basic Science Process Skills

Basic process skills are essential skills that provide a foundation for learning. Basic process skills include observing, classifying, communicating, measuring, concluding, predicting, experimenting, using space/time relationship and inferring (Zeidan & Jayosi, 2014; Gurses, Çetinkaya, Dogar, & Sahin, 2015; Delen & Kesercioğlu, 2012; Chabalengula, et al., 2012; Ozgelen, 2012). Chiappetta and Koballa (2002) explained some basic science process skills as follows:

i. Observing: Noting the properties of objects and situations using the five senses. It involves a description of what was actually perceived.

ii. Measuring: Expressing the amount of an object or substance in quantitative terms.

iii. Inferring: Giving an explanation for a particular object or substance in quantitative terms.

iv. Classifying: Relating objects and events according to their properties or attributes.

v. Predicting: Forecasting a future occurrence based on past observation or the extension of data.

vi. Communicating: Using words, symbols, or graphics to describe an object, action or event.

According to Skamp (2015), basic science process skills such as observing, using numbers and classifying are the foundation for the acquisition of integrated science process skills. Turiman et al. (2012) further reiterated that basic process skills are skills that must be mastered before mastering integrated process skills. For instance, students with observation ability can develop other skills such as concluding skills, communication, predictive measures, drawing conclusions. It could be concluded that students will need to master basic process skills to facilitate their ability to easily develop higher abilities. This explains why Gurses et al. (2015) indicated that basic process skills are usually experienced in primary levels because basic process skills need to be acquired in the early stages of life. For instance, young students can be given the opportunity to observe, handle things and explore the environment (Ango, 2002). Colvill and Pattie (2002) postulated that the activities which consist of basic and integrated process skills are the key factor or dimension of science literacy. Also, both basic and integrated scientific skills are important in any scientific investigation such as conducting projects and carrying out experiments (Zeidan & Jayosi, 2015). It is worth noting that these skills (both basic and integrated) which are obtained through experience and skill development through practice (Faruk & Lu, 2012) are needed in realizing the potential of Science and Technology to solve societal problems (Akinbobola & Afolabi, 2010). The acquisition of these skills will empower students to become problem solver especially multi-dimensional problems of the 21st century (Feyzioglu, 2009).

2.2.5 Integrated Science Process Skills

Integrated skills are more complex skills for conducting science experiments and solving problems in general (Mei, 2007). Integrated process skills include controlling variable, hypothesizing, experimentation, data interpretation controlling variables, defining operationally, formulating hypotheses, interpreting data, experimenting, formulating models and presenting information (Zeidan & Jayosi, 2015); Ozgelen (2012). Chiappetta and Koballa (2002) also introduced skills such as identifying the problem, identifying and controlling variables, formulating hypotheses, interpreting data, defining operationally, reading/constructing graphs and experimenting as integrated science process skills which are more complex skills than the basic skills. Similarly, (Shahali & Halim, 2010) mentioned identifying/controlling variables, stating hypothesis, designing, experiments, graphing/interpreting data and stating operational definition as integrated skills. According to (Gurses, Çetinkaya, Dogar, & Sahin, 2015; Delen & Kesercioğlu, 2012). Integrated science process skills (ISPS) can be accomplished by secondary and high school students. It is therefore expected that senior high school physics. Below is a brief description of what some of the integrated science skills entails.

i. Controlling variables: Manipulating and controlling properties that relate to situations events for the purpose of determining causation.
ii. Hypothesizing: Stating tentative generalization of observations or inferences that may be used to explain a relatively larger number of events but that is subject to immediate or eventual testing by one or more experiments.
iii. Experimentation: Testing a hypothesis through the manipulation and control of independent variables and noting the effects on a dependent variable: interpreting and presenting results in the form of a report that others can follow to replicate the experiment.
iv. Data Interpreting: Arriving at explanations, inference, or hypotheses from data that have been graphed or placed in a table. (Chiappetta & Koballa, 2002)

2.2.6 Students' Misconceptions in Science (Optics)

Ideas developed by students which differ from scientific explanation are known as misconceptions (Halim, Yong & Meerah, 2014). According to Eryilmaz (2002), misconceptions are beliefs which contradict accepted scientific theories. Kuczmann

(2017) is also of the view that misconceptions are beliefs which contradict scientifically recognized theories, but are seemingly well-founded on the basis of some practical experiments and experiences or logical conclusions. Simply put, misconception is the result of the lack of understanding of a concept which occurs when students nurture an inaccurate idea instead of correct knowledge.

All of us have misconceptions about the way the world works. Many of these are acquired early in life by inadequate observation and false assumptions, but others are spread by inexact textbooks and movies that do not reflect reality. Most misconceptions can be identified by careful observation and use of critical thinking strategies (Herr, 2008). It has also been revealed through findings in studies conducted in the past that students tend to develop the understanding about natural phenomenon before formal teachings are conducted (Halim, Yong, & Meerah, 2014). In the formal teaching setting, some factors could be suspected as the cause of misconception, namely the learning process, curriculum, and teacher's paradigm that learning is the transfer of knowledge (Kurniawan, 2018; Santyasa, Warpala and Tegeh, 2018; Üce & Ceyhan, 2019).

Also, many studies had proven that some physics subjects are difficult because of their abstract concepts (Aboagye, 2009; Johnson, 2017; Pablico, 2010). This obstacle causes misconceptions. Kuczmann (2017) in a study pointed out based on the character of students' errors that misconceptions among students is a reflection of a special deficiency of information. This deficiency may mean a deficiency of the knowledge of facts and of the knowledge of relationships between some knowledge. In a nutshell, misconceptions arise among students due to having poor understanding of scientific concepts (Kaewkhong, 2006).

Eshach (2010) asserted that several studies have reported on students' misconceptions about concepts in optics. Lawson (2010) reported on students' alternative conceptions about plane mirror reflection. Some studies reported on students' alternative ideas on vision and shadows (Chen 2009) while others dealt with students' ideas about refraction (Kaewkhong et al. 2008, 2010; Sengoren 2010). According to Kaewkhong et al. (2010), Thai high-school students confuse the meaning of light reflection and refraction; the direction of propagation of light; how light refraction occurs at an interface; and how to determine a position of image. These misconceptions became apparent when the students attempted to explain how an object submerged in a water tank is 'seen' by an observer looking into the tank from above and at an angle. Students often used the terms refraction or reflection inappropriately in their discussions. Galili and Hazan (2001) argued that these alternative conceptions arise because of students pre-existing ideas and beliefs based on their everyday experience with the light. A number of studies have also pointed out that misconceptions concerning vision, propagation of light and refraction exist among students at all levels have (Galili & Hazan, 2000; Mistrioti, 2003; Kaewkhong et al., 2010; Uzun, Alev & Kalal, 2013). For instance, it was found that students at the university think that light requires a material medium for propagation.

Various studies have discovered that some misconceptions are still prevalent among students although the existence of these misconceptions have been revealed overtime (Halim, Yong, & Meerah, 2014; Santyasa, Warpala, & Tegeh, 2018). The same misconception occurs and exists at primary and up to university level. For instance, Pablico (2010) reported that the most common misconception among physics and physical science group is the idea that gravity slows down the motion. Among the middle school science group, the most common misconception was that the force used to speed up is still there. Other prevalent misconceptions include the following ideas:

there is force when there is motion; there is no force when motion is slowing down; and there is no force when no pedaling and no brakes are applied (Pablico, 2010).

Misconceptions can have serious impact on student learning. Chang, Chen, Guo, Chen, Chang, Lin, Su, Lain, Hsu, Lin, Chen, Cheng, Wang and Tseng (2007) are of the opinion that students' misconceptions or alternative frameworks or alternative conceptions, can affect the acquisition of scientific knowledge. Also, misconceptions cause characteristic difficulties in the instruction of natural sciences subjects such as physics, chemistry, biology, and mathematics (Stein, Larrabee & Barman, 2008). The prevalence of misconceptions hinders students' learning of more advanced concepts, and as they continue to build up knowledge, it becomes more difficult to rectify the misconceptions. If students' initial understanding is not engaged, they may fail to grasp new concepts and information presented in the classroom, or they may learn them for purposes of a test but revert to their preconceptions outside the classroom (Pablico, 2010). Substantial evidence suggests that the holding of misconceptions can prevent students' further understanding of physics. As such, a key element of teaching physics is assessing pupils' current understanding and deciding how to proceed accordingly (Institute of Physic (IOP), 2021). There is therefore the need for the development of meaningful conceptual understanding among students because it is a key requirement for elimination of prevailing misconceptions associated with complex scientific phenomena. (Ramaila, 2021). Although misconceptions constructed at earlier ages are so strong that they are difficult to change, the conceptual change is necessary (Ürey & Çalık, 2008). Duit and Treagust (2003) proposed that in order for learning to occur, students must first critically evaluate misconceptions and revise them to be compatible with the discipline. Also, there is the need for effective teaching that develops deep learning. Teachers must employ student-centered approaches and engage students in optics lessons through active learning methods (Sokoloff, 2006) that uses a predict–observe–explain–synthesize learning cycle will allow students to confront, and then correct, their misconceptions.

2.2.7 Students' Knowledge and Understanding of the Concept of Optics

Although light is an everyday phenomenon that we constantly observe, scientific concepts of light are basic and yet important contents in physics education (Srisawasdi & Kroothkeaw, 2014). The study of optics in physics is very essential. Students' understanding of the concept of light and its properties will promote students' understanding of many scientific domains (Djanett, Fouad & Djaml, 2013). We often encounter the applications of the knowledge of optics in our everyday lives. Refraction and reflection are among the major topics in optics which students study in senior high schools in Ghana (Ministry of Education, 2010). However, according to Srisawasdi and Kroothkeaw (2014), a number of findings from previous studies indicated that students often displayed learning difficulties and hold misconceptions in physics concepts of light wave. For instance, though shadows are formed when rays of light are stopped by objects, students think that shadows can be conceived as an image, or as something belonging to an object (Anderson & Bach, 2005). Galili and Hazan (2000) explored high school and teacher-training college students' knowledge of light, vision and related topics. During the study, students were encouraged to draw diagrams or sketches to support their written answers. It was found that majority of the students' written descriptions and sketches describing the vision process made no reference to a physical relationship between the observing eye and the observed objects. Some students used expressions such as 'eyes can see', or 'I just open my eyes, and I see.' Also, students had the misconception that 'the image formed by a plane mirror was always present in the mirror whether or not it was observed', 'images were first created by a special material comprising the mirror; subsequently we looked in the mirror and saw them', 'when a converging lens was removed, a right-side-up image replaced the previously observed inverted image'. Personal observation reveals that students usually understand that a screen at the image location allows for indirect observation, but they often fail to understand how the image can be observed directly. These misconceptions suggest that ray diagrams can result in difficulties in understanding, especially when translating a real system into a ray diagram and vice versa. Nevertheless, when ray diagrams are used appropriately by applying them consistently in carefully designed exercises, they offer opportunities to eliminate conceptual conflicts and resolve misconceptions. In discussions about how an object is seen, students generally could not demonstrate a link between the eye and viewed object or image (Galili & Hazan, 2000; Heywood, 2005). Some students think that only looking at the object is sufficient to see it (Heywood, 2005; Şen, 2003). Students' diagrams or explanations on plane mirror image formation contain scientific mistakes or deficiencies (Galili & Hazan, 2000; Heywood, 2005). In another study, alternative conceptions learners held in terms of the roles that lens and screen play in image formation and the characteristics of the image formed when a lens with a larger diameter is used and when a portion of the lens is covered was investigated. Though most of the participants could not respond correctly in the situations presented in the questionnaire, almost all of them were found to have adequate conceptual understanding about the role of a lens in image formation (John, Molepo & Chirwa, 2017). Also, the teaching and learning of optics is reported challenging for instructors and students (Galili & Hazan, 2000). For instance, wave and particle nature of light has been found to be of considerable instructional challenge to both teachers and learners in diverse educational settings(Galili & Hazan, 2000).

2.2.8 Rationale for the Teaching of Elective Physics in Ghanaian Senior High Schools

Senior high school education provides the essential building blocks to continue to higher levels of education (tertiary). The general science programme offered at Ghanaian Senior High Schools level aims at equipping students with the necessary scientific concepts and skills using the inquiry methods of learning (Ministry of Education, 2010). The aims of the Senior High School Physics programme as spelt out in the physics syllabus are to:

i. Provide, through well designed studies of experimental and practical physics, worthwhile hands on educational experience to become well informed and productive citizens.

ii. Enable the Ghanaian society function effectively in a scientific and technological era, where many utilities require basic physics knowledge, skills and appropriate attitudes for operations

iii. Recognize the usefulness, utilization and limitations of the scientific methods in all spheres of life.

iv. Raise the awareness of inter-relationships between physics and industry, information, and communication technology (ICT), Agriculture, Health, and other daily experiences.

v. Develop in students, skills and attitudes that will enable them to practice science in the most efficient and cost-effective way.

vi. Develop in students' desirable attitudes and values such as precision, honesty, objectivity, accuracy, perseverance, flexibility, curiosity and creativity.

vii. Stimulate and sustain students' interest in physics as a useful tool for the transformation of society (Ministry of Education, 2010)

Physics, as a discipline, deals with the nature of matter and energy, their interactions and measurements. Physics is the most basic and fundamental natural science which involves universal laws and the study of the behaviour and relationships among a wide range of important physical phenomenon (Cutnell & Johnson, 2007). Physics is one of the oldest and probably the most developed of all the Sciences. It addresses the most fundamental questions regarding the nature of the physical universe. It asks questions such as; what is the nature of the universe? What is matter made of? What are the fundamental forces of nature? Physics therefore provides the underpinnings for all other physical sciences. The ultimate description of all physical systems is based on the laws of physical universe usually referred to as 'the laws of physics' (Onah & Ugwu, 2010). According to Onah and Ugwu (2010), physics is considered as consisting of scientific facts, principles, laws and generalizations derived from scientific investigations. The study of physics has had, and continues to have, a big impact on the world community. The ideas, skills and attitudes derived from the study of physics are being widely applied in various scientific and technological developments. As an example, development in renewable energy is serving the world profoundly and it is hoped that it will become more available in Ghana to complement other sources for meeting the energy needs of the country. There are specific examples of renewable energy in appropriate forms such as; electrical energy for operating simple equipment, and machinery, and for domestic use. The principles and applications of physics cut across the various spectrum of everyday life activities like walking, lifting, seeing and taking photographs. The principles and applications of physics cut across the various spectrums of everyday activities like walking, lifting objects, seeing, taking photographs using electrical and electronic gadgets among others (CRDD, 2010). Through the study of physics, students acquire, process and manipulative skills that enable them to predict accurately the outcome of various events such as the occurrence of the eclipse, effect of gravity and other forces and phases of the moon (Munene, 2014). According to Murei (2015), physics prepares learners for scientific and technological vocations. Physics is an important subject in the senior high school curriculum in Ghana and all over the world. It assists learners to apply the principles, knowledge acquired as well as skills and values to construct appropriate scientific innovations and inventions. To apply science and technology affectively depends on the acquisition of scientific knowledge, skills and attitude as a habit (Semela, 2010). To achieve this, it will include the teaching of physics at all level of education more importantly at the senior high (SHS) level in such a way that enables students to learn physics and therefore science effectively and efficiently. One approach is to adequately and proficiently handle physics topics more practically and interestingly in a student-centred way. However, in most Ghanaian classrooms, the teaching of physics places more emphasis on the accumulation of facts rather than on effective methods of inquiry (Bybee, Trawbridge & Powell, 2008).

2.2.9 Scope of Content of G.E.S. Syllabus on Physics Practical Work

The SHS elective physics syllabus builds upon the foundation laid in the junior high school integrated science at the basic level and SHS integrated science. The topics have been selected to enable students acquire the relevant knowledge, skills and attitudes needed to pursue science courses at the tertiary level of education, other institutions, apprenticeship and for life. The syllabus embodies a wide range of activities such as projects, experiments, demonstrations and scientific inquiry skills designed to bring out the resourcefulness and ingenuity of the physics students. (Ministry of Education, 2010). The physics syllabus has been structured to cover three years of SHS programme. Each year's work consists of sections with each comprising a number of units. There are seven main sections. of interest to this study is section four: Waves, with three units under it.

Unit 1: Reflection of light from plane and curved mirrors

Unit 2: Refraction of Light

Unit 3: Fibre Optics

A total of six periods per week is allocated to the teaching of physics in each week, with each consisting of forty minutes. The teachings periods allocated in Table 1.

Table 1: ***Weekly Theory and Practical Physics Periods***

Year	Practical work	Theory	Total
1	2	4	6
2	2	4	6
3	2	4	6

Source: Ministry of Education physics syllabus (2010)

According to the Ministry of Education Syllabus (2010):

i. Teachers should ensure that students are adequately prepared in theory before each practical class.

ii. Teachers should also ensure that practical works are started in SHS 1 alongside the theory classes.

iii. Three periods can be allocated for practical work and five periods for theory, if the time table in the school allows for that form of arrangement.

The objective of the practical oriented teaching is to guide how well the candidates understand the nature of scientific investigations and their capability in handling simple apparatus in an experiment to determine an answer to a practical question. It is also to determine their competence in skills acquired during their practical work over the three years of studies at the SHS level (Ministry of Education Syllabus, 2010).

2.2.10 Assessment

Assessment is a method for obtaining information in order to make informed decisions about curriculum, student learning and other educational programs. Stiggins (2002) pointed out two main purposes for assessment: assessment for accountability and assessment for learning. Teachers use assessment for learning to provide information for students to advance, rather than merely checking on student learning. Assessment can also help teachers improve the teaching-learning process by aligning assessment with the national content standards for physical education (Stiggins, 2002). One other importance of classroom assessment is to draw the attention of students to instructional priorities and influence them to concentrate on crucial aspects of what they learn in the school setting. Assessment is noted to be a powerful diagnostic instrument that enables teachers understand the areas in which students are having difficulty so they can concentrate their efforts in those areas (Ali, Sultana, & Marwat, 2010). Research has revealed that assessment helps students to focus on learning and better understand teacher expectations (James, Pellegrino, Chudowsky, & Glaser, 2001). There are many reasons for assessing elective physics students' performance, some are to classify or grade students and also to guide improvement whiles facilitating students' choice of option. Also, teachers can share assessment results with important education stakeholders including; parents, other teachers, community members and the learners themselves. Parents especially want to know how their children are doing in school. Regular reports from the teacher based on continuous assessment allow parents to know about their wards progress. With this knowledge in hand, all stakeholders especially parents and teachers can assist and support children with their studies during the school year (Jarvis, 2006).

According to Johnson (2017), assessment process consists of both measurement procedures (i.e. tests) and non-measurement procedures (e.g., informal observation). Assessment is needed for describing changes in students' performance as well as value judgements concerning the desired changes. When guided by a set of general principles, the process of assessment could be effective

2.2.11 Performance Assessment

Performance assessment is used to refer to assessment techniques that integrate science investigations, such as hands-on practical tasks to measure and evaluate a student's content and procedural knowledge, and has ability to use the knowledge in reasoning and solving problems. Students are able to demonstrate their knowledge, skills and work habit (Frey, 2018). Performance assessment is sometimes referred to as "alternative" assessment or "authentic" assessment. Authentic assessment focuses on the practical application of tasks in real-life setting (Reeves, 2000; Mueller, 2018). According to Mueller (2018), performance assessment is a form of assessment in which students are asked to perform real-world tasks that demonstrate meaningful application of essential knowledge and skills. Thus performance assessment is that which require students to demonstrate that they have mastered specific skills and competencies by performing tasks. Performance-based assessments are tasks conducted by students that enable them to demonstrate what they know about a given topic (Flynn, 2008). Reeves (2000) believes that the emphasis on performance assessment is the ability of learner in applying his/her knowledge and skills to real life simulations. He further states that there are five main aspects of performance assessment.

i. It is focused on complex learning,

ii. Engages higher-order thinking and problem-solving skills,

iii. Stimulates a wide range of active responses,

iv. Involves challenging tasks that require multiple steps,

v. Requires significant commitments of student time and effort.

According to Miller, Linn and Gronlund (2009) there are a number of advantages for using performance-based assessment; which includes:

i. They can clearly communicate instructional goals that involve complex performances in natural setting in and outside of the school.

ii. They can measure complex learning outcomes that cannot easily be measured by other means of assessments.

iii. They provide a means of assessing process or procedure as well as the product those results from performing a task (p. 266).

Despite the number of advantages of using performance-based assessments there are some limitations that must be taken care of; these include:

i. The unreliability of ratings of performances across teacher or across time for the same teacher.

ii. Their time-consuming nature.

iii. The relatively few extended performance assessments can be obtained within a given period and hence covering the lesson objectives entirely will be an issue (p. 268).

Similarly, Simonson, Smaldino, Albright and Zvacek (2000) discussed the several advantages of alternative assessment. First of all, they tend to simulate real-life contexts. Learners have opportunity to practice the authentic activities that they might encounter in real life. These activities allow them to transfer their skills to various real world related settings. Second, collaborative working is encouraged (Dikli, 2003)

Advocates of performance assessment calls for assessment types that give students the opportunity to better communicate what they learned. Performance-based assessments focus on affording students the opportunity to apply their knowledge by engaging in tasks requiring critical-thinking strategies (Flynn, 2008). The application of knowledge by students requires that they are equipped with skills that will empower them to design and carry out experiments, work with other students to accomplish tasks, demonstrate proficiency in using a piece of equipment or a technique and analysing of data. However, for performance assessment procedure to be effective, the task used or developed should be valid, reliable, and usable. The tasks should also be independent, complete, and unique. To validate the construct and content validity of an instrument, the items are subjected to the judgements of experts (Anthony-Krueger, 2001).

2.3 Summary of Related Literature

The constructivist theory advocates the promotion of a learner-centered learning classroom climate, where knowledge is constructed from experience. Learning results from a personal interpretation of knowledge. Also, learning is an active process in which meaning is collaborative with meaning negotiated from multiple perspectives. Learning should occur in realistic setting, where learning outcomes depend not only on the learning environment, but also the knowledge, purpose and motivations learn brings to the tasks. The purpose of process of learning involves the construction of meaning, which is continuous and active process. Learners have the final responsibility for their learning. Moreover, the constructivist hold that learning is an interpretive process as new information is given meaning in terms of the student's prior knowledge.

Teaching is not the transmission of knowledge but involves the organization of the situations in the classroom and the design of tasks in ways which promotes scientific learning. Teachers have three broad aims in relation to practical work can be categorized into three domains. They are procedural, conceptual and affective. Practical work in school is carried out in different ways. Predominantly, the work done in a laboratory simply verifies something already known by applying science process skills. Existing literature points to the important role performance assessment through practical activities plays in ensuring that students have the opportunity to apply their theoretical knowledge. It has also been established in previous literature that, at the SHS level, students should possess integrated skills such as defining operationally, formulating hypotheses, interpreting data, experimenting, formulating models and presenting information. Planning, performing and reasoning skills are all fundamental skills needed by students to be able to formulate hypothesis, perform experiments and interpret the data obtained. It is therefore a step in the right direction to assess the science process skills of SHS students to be abreast with their level of acquisition science process skills.

CHAPTER THREE

RESEARCH METHODOLOGY

3.0. Overview

This chapter entails a vivid description of the methodology used to arrive at the findings of the study. Under this chapter, issues such as population and sample size, sampling procedures, instruments and materials used for the study were discussed. This chapter entails a description of the research design employed in carrying out the study and a justification for the choice of the design. This chapter also gives an account of the instruments and procedure for data collection, processing and analysis.

3.1. Research Design

In this study, action research specifically practical action research was adopted as the research design that guided the study. A research design is a systematic plan outlining showing how the problem of investigation will be solved (Wills, 2003). The aim of action research is to address an actual problem in an educational setting. Thus, action researchers study practical issues that will have immediate benefits for education. Action research addresses a specific, practical issue and seeks to obtain solutions to a problem (Creswell, 2012; Cohen, Manion & Morrison, 2018). According to Cohen, Manion and Morrison (2018), action research is designed to bridge the gap between research and practice. They further purported that the aim of any action research project or programme is to bring about practical improvement, innovation, change or development of social practice and the practitioners' better understanding of their practices (Cohen, Manion & Morrison, 2018). The purpose of practical action research is to research a specific school situation with a view toward improving practice. It involves a small-scale research project, narrowly focuses on a specific problem or issue, and is undertaken by individual teachers or teams within a school or school district (Mills, 2011; Creswell, 2012)

To enable a researcher plan, implement, review and evaluate an intervention designed to improve practice or solve local problem, the scope of action research as a method has been recommended to be impressive. It can be used in almost any setting where a problem involving people, tasks and procedures cries out for solution, or where some change of feature results in a more desirable outcome (Creswell, 2012). Based on the characteristics and strength of action research, it is deemed appropriate for this study.

3.2. Population of the Study

Population of a study is the larger group to which the researcher would like the results of a study to be generalised (Lodico, Spaulding & voegtle, 2006). The target population is the group of interest to the researcher (Best & Kahn, 2006). It is the group from whom the researcher would like to generalise the results of the study (Lodico, Spaulding & Voegtle, 2006). Alvi (2016) also defines target population as all the members who meet the particular criterion specified for a research investigation. The accessible population is a portion of the population to which the researcher has reasonable access; it may be a subset of the target population. In other words, it is the population from which the researcher can realistically select subjects, which is also known as the available population (Gay, Mills & Airasian, 2012).

In this study, the target population comprised all general science students studying physics at Apam Senior High School in the Central Region, Ghana. This population is easily accessible to the researcher. The familiarity of the population and the study area to the researcher also enhanced easy access to vital information and other resources needed to effectively carry out the study. However, due to the limited academic period allotted for this study, the researcher involved only a portion of the target population as respondents. Therefore, the accessible population consisted of only second and third year science students studying physics. Also, first years were not selected to take part in the study because they were new in the school as at the time the study was conducted and had not covered much topics in the syllabus.

3.3. Sample and Sampling Procedure

A sample is a proportion or subset of a larger group (Fink, 2003). It can also be defined as a finite part of a statistical population whose properties are studied to gain information about the whole. It is a small group obtained from the accessible population (Mugenda & Mugenda,2003).

In this study, purposeful sampling was employed in selecting students that constituted the sample for the study. Second year science students studying physics were purposely selected because they have been studying physics for at least a year and have studied the topics under investigation. According to Creswell (2012), purposeful sampling is a qualitative sampling procedure in which researchers intentionally select individuals and sites to learn or understand the central phenomenon. The form two (2) students were therefore in a better position to perform the tasks in this study. The sample for the study was made up of a total of 45 respondents (form two science students studying physics)

3.4. Research Instruments

The research instruments used to collect data for this study was a questionnaire and teaching intervention. Pre-intervention and post-intervention practical tests were designed to determine students' level of acquisition of science process skills before and after the intervention. The intervention consisted of physics practical lessons on reflection and refraction designed with the purpose of guiding students to acquire and improve their science process skills. The physics practical lessons and questions on the pre-intervention and post-intervention were developed using the physics syllabus for senior high school as a guide.

This study also employed a questionnaire to gather additional information from the students on the impact of the intervention. The questionnaire was made up of four sections. Section one consisted of items meant to obtain background information of the students. Other items on the questionnaire were grouped under the three science process skills (measuring, inferring and data presentation) under investigation. A three-point Likert scale format consisting of Agree (A), undecided (U), Disagree (D) was used in the questionnaire to help students respond to the items on it.

3.5. Validity and Reliability of the Research Instruments

The instruments were validated through content validity. Content validity refers to the degree to which the items on an instrument represents the content that the items are designed to measure (Orodho, 2009). An expert judgement is the most common validation used in research (Fugarasti, Ramli & Muzzazinah, 2019). The Researcher applied content validity through the use of professionals in the field of science education. The researcher discussed the items with his supervisors, other lecturers and colleagues on whether the instruments accurately represent the concept of the study. Their ideas and inputs were considered and appropriately incorporated.

There are a number of different aspects to reliability. One of the aspects is to check for internal consistency. Internal consistency refers to the degree to which items that makes up a scale "hang together" or measure the same underlining construct (Pallant, 2007). According to Creswell (2012), one way to ensure that an instrument is reliable is to split the test in half and relate or correlate the items. This test is called the Kuder–Richardson split half test (KR-20, KR-21) (Creswell, 2012). In this study, the

Kuder–Richardson split half test was therefore used to test the reliability of the pre-intervention test and post-intervention test while Cronbach's alpha coefficient was used to check the reliability of the items on the questionnaire. The reliability values were calculated using values from the pilot testing. According to DeVellis (2003), Cronbach's alpha coefficient of a scale should be above 0.7 in order to be reliable, hence acceptable.

3.6. Data Collection Procedure

The Researcher obtained an introduction letter from the Department of Science Education, University of Education, Winneba introducing the researcher and the need to be assisted to collect data for the study. The headmaster and students involved in the study were briefed about the purpose of the study. According to Creswell (2012), a researcher must regard him/herself as a visitor and therefore show much respect by gaining permission before entering a site where the study will be conducted. Even though the Researcher is a teacher at the school where the study was conducted, it was deemed necessary to give reverence to all authorities in the study site. This was done to ensure effective collaboration and participations of the pupils and the school as a whole.

On the first day of data collection, pre-intervention practical test designed to measure students' level of acquisition of science process skills (measuring, inferring and data presentation) before the main intervention was administered. Students' responses to the pre-intervention test were marked and carefully analysed by the researcher to get informed on the science process skills of students. The results from the pre-intervention test also enabled the researcher decide on strategies to employ during the intervention stage. During the subsequent days of data collection, the students were taken through lessons (intervention) with the purpose of helping them acquire and improve their science process skills. Students' science process skills were again assessed using the post-intervention test. They were also made to respond to items on a questionnaire to inquire from them the impacts of the intervention.

Before the data collection, the research instruments (the questionnaire and pre-intervention test) were pilot tested in one of the senior high schools in the Cape Coast Metropolis. This enabled the researcher to assess the clarity of the items on the instruments so that those items found to be ambiguous were either discarded or modified to improve the quality of the research instruments and the data collected. Piloting also allowed the researcher to create familiarity with the instruments used (questionnaire and pre/post-intervention test).

3.6.1 Pre- intervention

The pre-intervention comprised two (2) practical questions under reflection and refraction. The pre-intervention exercise was aimed at measuring students' level of acquisition of science process practical skills (measuring, inferring and data presentation). The practical questions were made up of instructions for students to follow and conduct the practical at the physics laboratory. The materials needed for the practical were made available at the laboratory before the start of the practical exercise. The Researcher administered and supervised the pre-intervention exercises on Friday, 23th March, 2022 from 8:00 am – 10: 30 am. Students' responses to the pre-test were marked and carefully analysed by the Researcher to get informed on the strategies to employ and content to include in the intervention stage.

3.6.2 Intervention

Based on the information gathered during the analysis of the students' performance in the pre-intervention (practical test), weekly lesson plans were developed. The intervention comprises lessons on practical skills such as data presentation (tabulation and graphing), measuring and inferring. The development and execution of the intervention lessons was geared towards helping student respondents develop their practical process skills. The teaching strategies the Researcher employed included class demonstrations and group works. Students were given enough time to practice individually and in groups what has been demonstrated. Each lesson lasted for 2 hours followed by 30 minutes' exercise. The exercises that were conducted after each of the lessons were meant to assess students to ensure they understood lessons taught. The performance of the students on the task given after each lesson enabled the Researcher assess the effectiveness of the lessons.

3.6.3 Post Intervention

At the post-intervention stage, students were made to carry out two practical tests on reflection and refraction. The post-intervention tests were similar to that of the pre-intervention test. The same materials used in carrying out the pre-intervention test were used in carrying out the post-intervention tests. Students' performance in both test (pre-intervention and post-intervention) were analysed and their means compared for statistical difference. The comparison of the pre and post-intervention test scores were compared to assess and evaluate the efficacy of the intervention strategies used.

3.7. Data Analysis

Statistical Package for Social Sciences (SPSS) version 21 was used in analysing pre-test scores, post-test scores obtained from pre-intervention and post-intervention respectively. Data collected from the questionnaire was also analysed using SPSS. After editing and coding, the data was keyed into the computer using the Statistical package for Solutions and Services (SPSS) software. Before performing the desired data transformation, corrections were made after verification from the questionnaires and the database was generated. The data obtained from the questionnaire was analysed using descriptive statistics involving mainly frequency, percentage, mean and standard deviation.

In analysing the data on the questionnaire, values of 1 to 3 were assigned to the Likert scale format (i.e. (3) – Agree; (2) – Undecided; (1) – Disagree). A midpoint values of two (2) was chosen which indicate that, for each item answered, an average value above two (2) obtained was considered as a positive opinion (majority of the students agreeing to a statement) and mean values below 2 obtain was considered negative opinion (majority of the students disagreeing to a statement) (Pallant, 2011; Korb, 2013; Kent State University Libraries, 2021) The data collected from the pre-intervention test and post-intervention test at the pre-intervention and post intervention stages were statistically analysed to determine if there were any statistical differences between their means using paired sample t-test. Aside the Paired sample t-test used in analysing the data obtained from pre-intervention and post intervention, eta squared was also computed to determine the magnitude of the mean difference.

CHAPTER FOUR

PRESENTATION OF RESULTS AND FINDINGS

4.0. Overview

In this chapter, data collected were subjected to statistical analysis using the Statistical Package for Social Science (SPSS). The analysis was based on the scores obtained through pre-intervention test and post-intervention test as well as information obtained through questionnaire after the intervention. Information obtained was presented in cross tabulation. Frequencies and percentages were used in the analysis. Paired t-test analysis was also computed.

4.1. Demographic Data of Respondents

The study involved a total of 45 Senior High School Form Two physics students in Apam Senior High School in the central region of Ghana. Out of the 45 students, majority of the students 28 (62.2%) were males and the rest 17 (37.8%) were females. The details of the age distribution of student respondents are presented in Table 2.

Table 2: ***Demographic Data of Respondents (n=45)***

Demographic Data	Frequency	Percentage (%)
Age(in years)		
15 years and below	10	22.2
16-18 years	26	57.8
Above 18 years	9	20.0
Sex		
Male	28	62.2
Female	17	37.8

From Table 2 above, majority of the respondents, 26(57.8%) had their ages between 16 and 18 years. Out the 45 respondents, only 10(22.2%) were below 15 years and 9(20.0%) were above 18 years.

4.2. Research question 1: what are students' appropriate and inappropriate responses for measuring, inferring and data presentation in reflection?

Research question 1 sought to ascertain students' strengths and weaknesses in reference to their science practical process skills (measuring, inferring and data presentation) in optics (reflection). The results are presented in Table 3.

Table 3: ***Students Performance on Reflection Task (Pre-intervention test)***

Process Skills	Specific Skills Assessed	FS f(%)	PS f(%)
Measuring	• Complete traces	29(64.4)	16(35.6)
	• Correct values of angle of incidence (i) measured to 1 dp	31(68.9)	14(31.1)
	• Correct values of angle of reflection (r) measured to 1dp	27(60.0)	18(40.0)
	• Computing the difference between the values of i and their corresponding values of r correctly	37(82.2)	8(17.8)
Data presentation	• Composite table showing at least i, r and (i-r) with correct units if any	24(53.3)	21(46.7)
Inferring	• The significance of the practical accurately explained	22(48.9)	23(51.1)
	• The difference between i and r accurately explained	25(55.6)	20(44.4)

Note: FS = Full Score, PS = Partial Score

This section discusses students' level of acquisition of science practical process skills before the intervention. Table 3 contains a record of students' performance on the reflection task. Specifically, the table comprises the number of students who obtained full score and those who did not in the various items under the main processing skills (measuring, inferring and data presentation) under study. There were a number of errors committed by students and evidence of display of lack of sufficient knowledge in certain area of the various process skills under study.

Though most of the students drew traces, there were no arrows on the rays of a number of their traces rendering them as just lines. This made it difficult to distinguish between the incident ray, reflected ray and the normal. Thus, resulted in 16 (35.6%) of the students not scoring the full marks. See Appendix D (a and b), being examples of the work of a student which was incomplete and had no arrows. This was the case of many of the students during the pre-intervention test.

About one-third 14 (31.1%) and 18(40.0%) of the students were unable to accurately measure the angles of incidence and reflection. This can largely be attributed to students' inability to use the protractor in measuring. Kallats (2001) sees practical works as a means to verify a science principle, or theory already known to students. In this current study, about half 23(51.1%) of the students could not accurately determine and explain the significance of the reflection task they performed. Thus, they were not able to relate the theory lesson they were taught in the classroom on reflection to the practical task on reflection. The practical was aimed at verifying the laws of reflection. The example shown in Appendix D (c) is an indication that the students had deviated. The student was concentrating on the uses of the mirror used in the experiment instead of the experiment as a whole.

In presenting data obtained during the practical, a number of students did not record all their values in one table. Instead, they had their values scattered all over making it difficult to read. There were inconsistencies in values recorded. Thus, values in column were recorded in different decimal places. Also, some of the values recorded were without unit. As a result, 21 (46.7%) of the students could not score full marks in data presentation. Appendix D (d & e) are excerpts from the write up of some students who had their values recorded in different tables.

Findings from Table 3:

Measuring

1. A significant number of students (about 40%) were unable to accurately measure angles of incidence (i) and angles of reflection (r) using the protractor and about 60% were able to measure.
2. Most of such students measured angles and missed the value accurately by 0.5° to 1.0°. The use of the protractor to accurately measure angles was a challenge to most of the students.

Data presentation

1. About half of the students (46.7%) could not accurately present data obtained through experiments.

Inferring

1. A substantial number of the students could not precisely predict the significance of the reflection practical they conducted. Students were not familiar with the experiment to verify the laws of reflection.

4.3. Research Question 2: What are students' appropriate and inappropriate responses on refraction tasks which involve measuring, data presentation and inferring?

Research question 2 was to find out students' appropriate and inappropriate response to refraction task which involve measuring angles of incidence and refraction, tabulating the angles, determining the sines and cosines of these angles, and then plotting them. The students are then to infer the significance of the resulting plot.

The results are presented in Table 4. Table 4 contains a record of students' performance on the refraction task. Specifically, the table comprises the number of students who obtained full score and those who did not in the various items under the main processing skills (measuring, inferring and data presentation) under study.

Table 4: ***Students Performance on Refraction Task (Pre-intervention test)***

Process Skills	Specific Skills Assessed	FS f(%)	PS f(%)
Measuring	• Complete traces	23(51.1)	22(48.9)
	• Correct values of incidence angles (i) to 1 dp	33(73.3)	12(26.7)
	• Correct values of angle of refraction (r)to 1 dp	29(64.4)	16(35.6)
	• Sin i and sin r computed correctly	41(91.1)	4(8.9)
	• Slope of the graph determined correctly	34(75.6)	11(24.4)
Data Presentation (Tabulation)	• Composite table showing at least i, r, sin i and sin r, with correct units	28(62.2)	17(37.8)
Data Presentation (Graphing)	• Axes distinguished and labelled correctly	39(86.7)	6(13.3)
	• Reasonable scale	43(95.6)	2(4.4)
	• Five points correctly plotted	28(62.2)	17(37.8)
	• Line of best fit	36(80.0)	9(20.0)
	• Large right-angled triangle for calculating slope	42(93.3)	3(6.7)
Inferring	• Explanation of the significance of the practical	28(62.2)	17(37.8)
	• Explanation of the significance of the slope obtained from the graph correctly	25(55.6)	20(44.4)

Note: FS = Full Score, PS = Partial Score

This section discusses students' level of acquisition of science practical process skills before the intervention. Table 4 contains a record of students' performance on the refraction task. Specifically, the table comprises the number of students who obtained full score and those who did not in the various items under the main process skills (measuring, inferring and data presentation) under study. As young scientists, its essential that senior high school physics students demonstrate some sufficient level of science process skills for the effective learning of science at all levels. Nevertheless, there were a number of errors committed by students and evidence of display of knowledge as well as lack of sufficient knowledge in certain area of the various process skills under study.

Though most of the students drew traces, there were no arrows on the rays of a number of their traces rendering them as just lines. This made it difficult to distinguish between the incident ray, refracted ray, emergent ray and the normal. Thus, resulted in about half 22(48.9%) of the students not scoring the full marks. Below are some examples shown in Appendix D (f and g).

About one-third 12(26.7%) and 16(35.6%) of the students were unable to accurately measure the angles of incidence and refraction. This can largely be attributed to students' inability to use the protractor in measuring angles. This was the case because most of the students used protractor in measuring angles whilst a few of them use compass while they were engaged with pre-intervention test on refraction, this was an observation made vis-a-vis.

The experiment on refraction was meant to verify the refractive index of glass. However, only 25(55.6%) of the students could accurately explain the significance of the refraction task they performed. Thus, they were not able to relate the theory lesson they were taught in the classroom on refraction to the practical task on refraction.

In presenting data obtained during the practical, a number of students did not record all their values in one table. Instead, they had their values scattered all over making it difficult to read, see Appendix D (h). There were inconsistencies in values recorded. Thus, values in column were recorded in different decimal places. Also, some of the values recorded were without unit. As a result, 17 (37.8%) of the students could not score full marks in data presentation (Tabulation).

The second aspect of the data presentation tested students' ability to present data graphically. All except 2 (4.4%) of the students used reasonable scale ensuring that their graph occupied at least two-third of the graph sheet. Majority 39 (86.7%) of the students had their axes distinguished and labelled correctly while a few 6 (13.3%) of the students did not either label their axes or labelled them wrongly. Some of these students were not specific with their axis labelling so they labelled it as y and x instead of sin i and sin r respectively. Also worth noting is that 17 (37.8%) of the students had challenges in accurately plotting values obtained during the practical. However, the line of best fit of most of the graphs drawn were accurate. Except for 3 (6.7%) whose triangles were too small, all the students constructed large right-angled triangle for calculating slope. Though there was a clear instruction that students should evaluate the slope of their graph, some students obtain their slope using values from the table of values. Appendix D (i) is an extract from the write up of a student who did not label his axes and had no triangle for calculating for slope.

In Appendix D (j, k and l) below, the students selected values from their table to calculate for slope instead of using values from the graph. Using values obtained from a large triangle drawn to the line of best fit could give a more accurate value for the slope (which represents the refractive index of glass). Appendix D (m) also provides evidence of the inconsistences in values recorded by some students as shown in the second and third column.

It must also be noted that the value of slope obtained by most of the students during the pre-intervention stage were not within the appropriate range (as low as 1.2 and above 1.6). Compare to the refractive index of glass which is 1.5. For students who calculated their slope from the graph. it is evident that most of the students conducted the practical with low level of accuracy during the pre-intervention test. However, majority of the students are equipped with some level of practical process skills in the area of measuring, data presentation and making inferences.

Findings from Table 4:

Measuring

1. About 22 (48.9%) out of 45 students could not correctly make complete traces of the glass prism.

Data Presentation

1. A significant percentage of the students lack sufficient skill of presenting data. Specifically, 17(37.8%) of the students could not correctly plot points on a graph. Also, majority of the students could not compute the slope of a graph.
2. Majority 39(86.7%) of the students possessed the skill of distinguishing between axes and labelling of axes, choosing reasonable scales, drawing of the line of best fit and drawing of large triangle for calculating slope

Inference

1. A significant percentage of the students (44%) lack sufficient skill of making inferences and interpreting data which is an essential integrated process skill. The students could not explain the significance of the slope obtained by dividing change in sine i by change in sine r. Students were not familiar with the experiment to determine refractive index of glass.

4.4. Research question 3: what impact has the teaching intervention had on students' ability to acquire science practical process skills?

The teaching strategies the Researcher employed included class demonstrations and group works. The purpose of the questionnaire was to seek students' opinion on the impact of the teaching intervention aimed at helping them acquire and improve their science practical process skills (measuring, inferring and data presentation). The information gathered from the students are presented in Table 5.

Table 5: ***Students' opinion on the impact of the teaching intervention***

S/N	Statements	Agree	Undecided	Disagree	M	SD
1	I like the class where the teacher demonstrates to us what to do.	37(82.2%)	3(6.7%)	5(11.1%)	2.71	2.454
2	The demonstrations by the teacher made it easier for me to acquire practical skills	40(88.9%)	1(2.2%)	4(8.9%)	2.80	2.357
3	I like the class where the teacher does all the talking and tells us all the answers.	23(51.1%)	5(11.1%)	17(37.8%)	2.13	3.166
4	My interaction with my teacher and other students in groups enhanced my ability to measure and present data	35(77.8%)	3(6.7%)	7(15.6%)	2.62	2.499
5	My understanding into how to make inferences from results obtained during practical was enhanced	37(82.2%)	1(2.2%)	7(15.6%)	2.67	2.314
6	I have gained confidence in practicing and applying what has been taught in the physics class	41(91.1%)	0(0.00%)	4(8.9%)	2.82	2.319

The results as displayed in Table 5 indicates that the respondents (students) are pleased with the teaching method employed during the intervention lesson. Out of the

45 students, 37(82.2%) of them pointed out that they are able to learn better when the teacher demonstrates to them what to do. Majority of the students 40(88.9%) further mentioned that they are able to acquire practical skills easily when the teacher teaches through demonstration.

The respondents were of divided view when asked whether they prefer a class where the teacher does all the talking and tells students all the answers. About half of the students 23(51.1%) pointed out that they enjoy such a class. According to Faruk and Lu (2012), science process skills are obtained through experience and skill development through practice. In this current study, all except 10(22.3%) of the respondents were of the view that the teacher-students and student-students dialogue and interactions that occurred during the intervention lesson enhanced their ability to acquire some practical process skills such as data presentation and measuring. Similarly, most of the students 37(82.2%) were of the opinion that the intervention lesson helped them to improve upon their ability to make inferences during practical. Almost all the students 41(91.1%) agree that they have gained confidence in practicing and applying the theoretical knowledge being taught in their physics class due to the practical process skills they have acquired. It is obvious from the responses that the intervention lesson provided a fertile ground for students to develop their science practical process skills.

Findings from Table 5:

1. The positive feedback obtained from the students indicate that the intervention lesson enhanced students' basic and integrated practical process skills such as data presentation, measuring, making inferences and data interpretation.
2. The positive impact of the intervention was attributed to the teaching method (demonstration by the teachers and team work among students) employed.

4.5. Research question 4: what are the performances of physics students engaged in science practical process skills of measuring, inferring and data presentation in reflection and refraction?

Research question 4 sought to find out and compare the performance of students in science practical process skills before and after the intervention lesson. This data and its analysis also enabled the researcher determine the impact of the intervention lesson on students' performance. The performances of students in the pre-intervention and post-intervention test were analysed and recorded in Table 6 and 7. The results presented in these tables enabled the researcher answer the fourth research question.

Table 6: ***Paired sample t-test results (Reflection)***

Process Skills	**Scores**	**Std. Deviation**	**Mean**	**Sig.(2-tailed)**	**Eta-squared**	**Interpretation**
Measuring	Pre-test scores	2.414	8.24	0.000	0.855	P<0.05, sig. diff. Large effect
	Post-test scores	1.087	14.33			
Data presentation	Pre-test scores	0.490	1.62	0.040	0.093	P<0.05, sig. diff Large effect
	Post-test scores	0.562	1.84			
Inferring	Pre-test scores	1.485	2.02	0.000	0.334	P<0.05, sig. diff Large effect
	Post-test scores	1.241	3.22			

Eta Square: Small effect (0.01), moderate (0.06), large (0.14) (Cohen 1988)

Eta (η^2) = $\frac{t^2}{t^2+(N-1)}$

A paired sample t-test was conducted to evaluate the impact of the intervention lesson on students' performance in measuring. There was a statistically significant increase in the students' performance from pre-intervention test (M = 8.24, S.D = 2.414) to the post-intervention test (M = 14.33, S.D = 1.087), t(44) = -16.087, P<0.05 (see appendix E). This indicates a statistically significant difference between the pre-intervention and post-intervention scores. The eta squares (effect size) statistics was computed to determine the magnitude of the effect of the intervention. The eta squares value of 0.855 indicates a large effect.

A paired sample t-test was conducted to evaluate the impact of the intervention lesson on students' performance in their ability to make inferences. There was a statistically significant increase in the students' performance from pre-intervention test

($M = 2.02$, $S.D = 1.485$) to the post-intervention test ($M = 3.22$, $S.D = 1.241$), $t(44) = -4.698$, $P<0.05$. This indicates a statistically significant difference between the pre-intervention and post-intervention scores. The eta squares (effect size) statistics was computed to determine the magnitude of the effect of the intervention. The eta squares value of 0.334 indicates a large effect.

A paired sample t-test was conducted to evaluate the impact of the intervention lesson on students' performance in their ability to present data. There was a statistically significant increase in the students' performance from pre-intervention test ($M = 1.62$, $S.D = 0.490$) to the post-intervention test ($M = 1.84$, $S.D = 0.562$), $t(44) = -2.119$, $P<0.05$. This indicates a statistically significant difference between the pre-intervention and post-intervention scores. The eta squares (effect size) statistics was computed to determine the magnitude of the effect of the intervention. The eta squares value of 0.093 indicates a large effect.

The overall significant value for all the process skills (Measuring, Inferring and Data presentation) examined under reflection was 0.000 (i.e. $P<0.05$). The eta squares value of 0.801, which indicates a large effect was obtained. This means that there was a statistically significant difference between pre-intervention and post-intervention scores. It could be inferred from the results that the intervention lessons significantly improved students' ability to measure, present data and make inferences. This resulted in students' overall high performance in the reflection task. A careful observation of the pre-intervention and post-intervention mean values of the various process skills revealed that the intervention largely improved students' ability to measure (Pre-intervention mean = 8.24 and Post-intervention mean = 14.33). This is also evident from the very high eta squared value obtain for the process skill (measuring). A similar study was carried out to investigate the effect of practical activities on secondary school students' process skill acquisition in Abuja Municipal Area Council. The results revealed that practical activity method was more effective in fostering students' acquisition of science process skills than the lecture method. (Nwagbo & Chukelu, 2011).

Table 7: ***Paired sample t-test results (Refraction)***

Process Skills	Scores	Std. Deviation	Mean	Sig.(2-tailed)	Eta-squared	Interpretation
Measuring	Pre-test scores	1.725	14.98	0.000	0.547	P<0.05, sig. diff.
	Post-test scores	1.507	17.16			Large effect
Inferring	Pre-test scores	1.587	2.27	0.517	-	P>0.05, no sig. diff.
	Post-test scores	1.408	2.47			
Data presentation	Pre-test scores	1.798	8.76	0.951	-	P>0.05, no sig. diff.
	Post-test scores	1.941	8.78			

A paired sample t-test was conducted to evaluate the impact of the intervention lesson on students' ability to measure, present data and make inferences in the refraction task. There was a statistically significant increase in the students' performance in measuring from pre-intervention test (M = 14.98, S.D = 1.725) to the post-intervention test (M = 17.16, S.D = 1.507), t(44) = - 7.293, P<0.05. This indicates a statistically significant difference between the pre-intervention and post-intervention scores. The eta squares (effect size) statistics was computed to determine the magnitude of the effect of the intervention. The eta squares value of 0.547 indicates a large effect.

The intervention lesson did not produce any significant effect on students' performance in the refraction task pertaining to data presentation (Pre-test mean = 8.76, post-test mean = 8.78) and making inferences (Pre-test mean = 2.27, post-test mean = 2.47). This implies that the intervention lesson did not result in the improvement of students' process skills (data presentation and making inferences) with regards to the refraction task.

Findings from Table 6 and 7:

The intervention lesson improved the performance of the students in terms of acquiring and applying their science practical process skills in conducting practical work. Students' performance in measuring, presenting data (Tabulation and graphing) and interpreting data was improved.

4.6. Discussion

Research Question 1: What are students' appropriate and inappropriate responses for measuring, inferring and data presentation in reflection?

The findings from the previous study align with the arguments presented in the literature regarding the significance of practical experiences in science education. The study emphasizes the importance of practical work in science to make it meaningful for students.

Measuring: The study indicated that a significant number of students (about 40%) struggled with accurately measuring angles of incidence and angles of reflection using a protractor. This finding is consistent with the literature that emphasizes the need for students to develop practical process skills to engage meaningfully in science. Doosti (2014), Hofstein and Mamlok-Naaman (2007) argue that practical experiences in science provide students with opportunities to develop skills such as measurement, which are essential for understanding scientific concepts. The findings suggest that without adequate measurement skills, students may struggle to accurately apply scientific principles and draw valid conclusions.

Data presentation: Approximately 46.7% of students were unable to accurately present data obtained through experiments. This finding also aligns with the previous literature, which highlights the importance of data presentation skills in science education. Effective data presentation allows students to communicate their findings and draw meaningful conclusions. Doosti (2014), Hofstein and Mamlok-Naaman (2007) stress that engaging in practical work enables students to develop skills in organizing and presenting data. The study's findings suggest that without these skills, students may face challenges in effectively communicating their scientific observations and results.

Inferring: The study found that a substantial number of students struggled to predict the significance of the reflection practical they conducted and were not familiar with the experiment to verify the laws of reflection. This finding is consistent with the literature, which emphasizes the importance of students' ability to make connections and inferences from practical experiences. Doosti (2014), Hofstein and Mamlok-Naaman (2007) argue that practical work helps students understand the underlying scientific principles and encourages them to make inferences based on their observations. The study's findings suggest that without a clear understanding of the purpose and expected outcomes of experiments, students may struggle to infer the significance of their practical work.

In summary, the findings from the previous study align with the arguments made in the literature that practical experiences are crucial for meaningful science education. The study's findings emphasize the need for students to develop science practical process skills, such as measurement, data presentation, and inference, to engage effectively in practical work and understand scientific concepts. By addressing these skills, educators can enhance students' engagement, comprehension, and appreciation of science.

Research Question 2: What are students' appropriate and inappropriate responses on refraction tasks which involve measuring, data presentation and inferring?

The findings presented suggest that there are certain deficiencies in the practical skills and data presentation abilities of the students involved in the study. Specifically, a large percentage of students struggled with making complete traces of a glass prism and plotting points on a graph. Additionally, many students were unable to compute the slope of a graph or explain the significance of certain calculations related to determining the refractive index of glass.

These findings align with the literature that emphasizes the importance of practical work in science education. Kallats (2001) views practical work as a means to verify scientific principles or theories that students already know. However, the findings suggest that a significant portion of the students lacked the necessary skills to effectively engage in practical activities and draw meaningful conclusions from their experiments.

The literature on science education often highlights the significance of hands-on activities and data analysis skills in fostering students' understanding of scientific concepts. The findings from this study indicate that there is a need for improvement in these areas. The high percentage of students who struggled with making complete traces of the glass prism and plotting points on a graph may indicate a lack of precision and attention to detail, which are crucial in scientific investigations.

Moreover, the difficulty in interpreting data and making inferences points to a gap in the students' understanding of the experimental process and the underlying concepts. The inability to explain the significance of the slope obtained from certain calculations suggests a lack of comprehension regarding the relationship between variables and the meaning of the results obtained.

To address these issues, it may be beneficial to provide students with more opportunities for hands-on experimentation and data analysis. Additionally, explicit instruction and practice in skills such as graphing, interpreting data, and making inferences should be incorporated into the curriculum (Monhardt & Monhardt, 2006). This will help students develop a deeper understanding of scientific principles and enhance their ability to engage in scientific inquiry.

Overall, the findings from this study highlight the importance of practical work in science education while also pointing out areas where students may need additional support and instruction. By addressing these deficiencies, educators can help students develop the necessary skills and competencies to excel in scientific investigations and enhance their understanding of scientific concepts.

Research Question 3: What impact has the teaching intervention had on students' ability to acquire science practical process skills?

The findings presented indicate that the intervention lesson had a positive impact on students' practical process skills, including data presentation, measuring, making inferences, and data interpretation. The positive feedback obtained from the students suggests that their skills improved as a result of the intervention.

These findings are consistent with the literature, particularly the viewpoint expressed by Faruk and Lu (2012), which states that science process skills are acquired through experience and skill development through practice. The intervention lesson in this study provided students with an opportunity to actively engage in hands-on activities and practice their practical skills, leading to improvements in various areas.

The positive impact of the intervention lesson can be attributed to the teaching method employed, specifically the demonstration by the teachers and the team work among students. This aligns with the literature, which emphasizes the importance of active learning and cooperative learning strategies in science education. By demonstrating the practical skills and encouraging teamwork, the teachers created an environment that facilitated skill development and enhanced students' understanding of scientific concepts (Monhardt & Monhardt, 2006).

Numerous studies have highlighted the effectiveness of hands-on activities, demonstrations, and collaborative learning in promoting the acquisition of science process skills. These approaches provide students with opportunities to engage in authentic scientific practices, where they can manipulate materials, collect data, analyze results, and draw conclusions. Through repeated practice and exposure to different tasks, students gradually develop competence in practical skills and become more proficient in conducting scientific investigations.

The positive feedback obtained from the students in this study suggests that the intervention lesson effectively promoted their practical process skills. This reinforces the idea that hands-on experiences and collaborative learning can significantly contribute to the development of these skills. It also underscores the importance of incorporating such teaching methods into science education to enhance students' overall understanding and competency in scientific practices.

In conclusion, the findings from this study align with the literature, emphasizing that science process skills are acquired through experience and skill development through practice. The positive impact of the intervention lesson on students' practical process skills further supports the effectiveness of hands-on activities, demonstrations, and collaborative learning in science education. By implementing these strategies, educators can enhance students' engagement and proficiency in practical skills, thereby fostering their scientific inquiry abilities and conceptual understanding.

Research question 4: What are the performances of physics students engaged in science practical process skills of measuring, inferring and data presentation in reflection and refraction?

The findings presented indicate that the intervention lesson was effective in improving students' acquisition and application of science practical process skills. Specifically, their performance in measuring, presenting data (tabulation and graphing), and interpreting data showed improvement.

These findings align with the literature, particularly the study by Nwagbo and Chukelu (2011), which suggests that the practical activity method is more effective in fostering students' acquisition of science process skills compared to the lecture method. The practical activity method emphasizes hands-on experiences and active engagement in scientific investigations, allowing students to directly interact with materials, collect data, and apply their skills in real-world contexts.

By actively participating in the intervention lesson, students had the opportunity to practice and apply their science practical process skills. This hands-on approach likely enhanced their understanding and proficiency in tasks such as measuring, presenting data, and interpreting data. The practical nature of the activities likely allowed students to see the relevance and application of these skills, leading to improved performance.

The effectiveness of the intervention lesson in enhancing students' science practical process skills supports the notion that active learning methods, which prioritize student engagement and application of knowledge, are more beneficial for skill development. Practical activities provide opportunities for students to experience the scientific process firsthand, fostering a deeper understanding of concepts and improving their ability to apply these skills in practical contexts (Addo-Wuver & Asare 2021).

It is important to note that the improved performance observed in the intervention lesson may also be attributed to other factors, such as the instructional design, teacher guidance, or the specific activities implemented. However, the overall finding that the intervention lesson positively impacted students' acquisition and application of science practical process skills is consistent with the literature and proves the effectiveness of hands-on, active learning approaches.

In conclusion, the findings from this study suggest that the intervention lesson was successful in improving students' science practical process skills, particularly in measuring, presenting data, and interpreting data. This aligns with the literature, which highlights the effectiveness of practical activity methods in fostering these skills. By providing students with opportunities for active engagement and application of knowledge, educators can enhance students' proficiency in science process skills and promote a deeper understanding of scientific concepts.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.0. Overview

This chapter entails a summary of the findings of the study. The recommendations made based on the findings of the study and suggestions for further research were also presented in this chapter. This chapter also contains the conclusions made based on the findings, recommendations and suggestions given in the study.

5.2. Summary of Key Findings

There were 5 findings revealed through the studies which were significant and worth noting. These are summarised below.

1. A significant number of students (about 40%) were unable to accurately measure angles of incidence (i) and angles of reflection (r) using the protractor and about 60% were able to measure. Most of such students measured angles and missed the value accurately by 0.5° to 1.0°. The use of the protractor to accurately measure angles was a challenge to most of the students.
2. About half of the students (46.7%) could not accurately present data obtained through experiments. A substantial number of the students could not precisely predict the significance of the reflection practical they conducted. Students were not familiar with the experiment to verify the laws of reflection.
3. About 22 (48.9%) out of 45 students could not correctly make complete traces of the glass prism. A significant percentage of the students lack sufficient skill of presenting data. Specifically, 17(37.8%) of the students could not correctly plot points on a graph. Also, majority of the students could not compute the slope of a graph. Majority 39(86.7%) of the students possessed the skill of

distinguishing between axes and labelling of axes, choosing reasonable scales, drawing of the line of best fit and drawing of large triangle for calculating slope.

4. A significant percentage of the students (44%) lack sufficient skill of making inferences and interpreting data which is an essential integrated process skill. The students could not explain the significance of the slope obtained by dividing change in sine i by change in sine r. Students were not familiar with the experiment to determine refractive index of glass.
5. The positive feedback obtained from the students indicate that the intervention lesson enhanced students' basic and integrated practical process skills such as data presentation, measuring, making inferences and data interpretation.

The positive impact of the intervention was attributed to the teaching method (demonstration by the teachers and team work among students) employed. The intervention lesson improved the performance of the students in terms of acquiring and applying their science practical process skills in conducting practical work. Students' performance in measuring, presenting data (Tabulation and graphing) and interpreting data was improved.

5.3. Conclusion

This study has shown that students who have done 2 years of Senior High School physics still had shortfalls pertaining to practical science process skills. It is therefore crucial that science teachers continuously engage their students with the appropriate content that will help them measure their science process skills.

Findings from this current study have revealed that teaching by demonstration is an effective method of helping students acquire and improve upon science process skills. This method of teaching coupled with others should be employed by science teachers to the benefit of their students.

Science practical process skills are requisite to students' meaningful understanding of science concepts, principles and laws. However, students' inappropriate responses whilst measuring, making inferences and presenting data requires that more attention is paid to helping them develop their science practical process skills. The ability to measure using simple instruments like meter rule, protractor and present data in tables, graphs should be at the fingertips of senior high school students. Assessing your students' science process skills as a science teacher and making efforts to aid them develop their skills is a great step in ensuring students effectively study and understand science.

5.4. Recommendations

Based on the key findings and the conclusions drawn from the study, the researchers would like to make the following recommendations.

1. Senior high school physics teachers should continuously assess and be abreast with their students' science process skills.
2. Senior high school students should be taught how to use the protractor in accurately measuring angles.
3. Senior high school physics teachers should try their possible best to link specific theory lessons learnt in the physics classroom to specific practical conducted in the laboratory. This will enable students know why certain practical activities are conducted and make accurate inferences.
4. Science practical process skills such as measuring, making inferences, data presentation and interpretation should be taught in the physics classroom. This will enhance science students' efficiency in understanding science through experimentation.

5. Senior high school physics teachers should teach science practical process skill via demonstrations and also allow for student-students interactive learning through team work.

5.5. Suggestions for Further Study

Further studies should:

1. be extended to other senior high schools in the Central Region as a whole to assess students' science practical process skills.
2. ensure that data is collected at different times across the nation to confirm the consistency of the information gathered from students for effective generalization.
3. employ demonstration method of teaching and other methods of teaching to ascertain their effectiveness in enhancing senior high school students' science practical process skills.
4. involve other topics in physics and other subject areas such as Biology and Chemistry.

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APPENDICES

APPENDIX A: PRE AND POST-INTERVENTION TASKS

UNIVERSITY OF EDUCATION, WINNEBA

FACULTY OF SCIENCE EDUCATION

DEPARTMENT OF SCIENCE EDUCATION

PRE-INTERVENTION PRACTICAL TEST FOR STUDENTS

An intervention test designed to assess physics students practical process skills in optics (reflection and refraction).

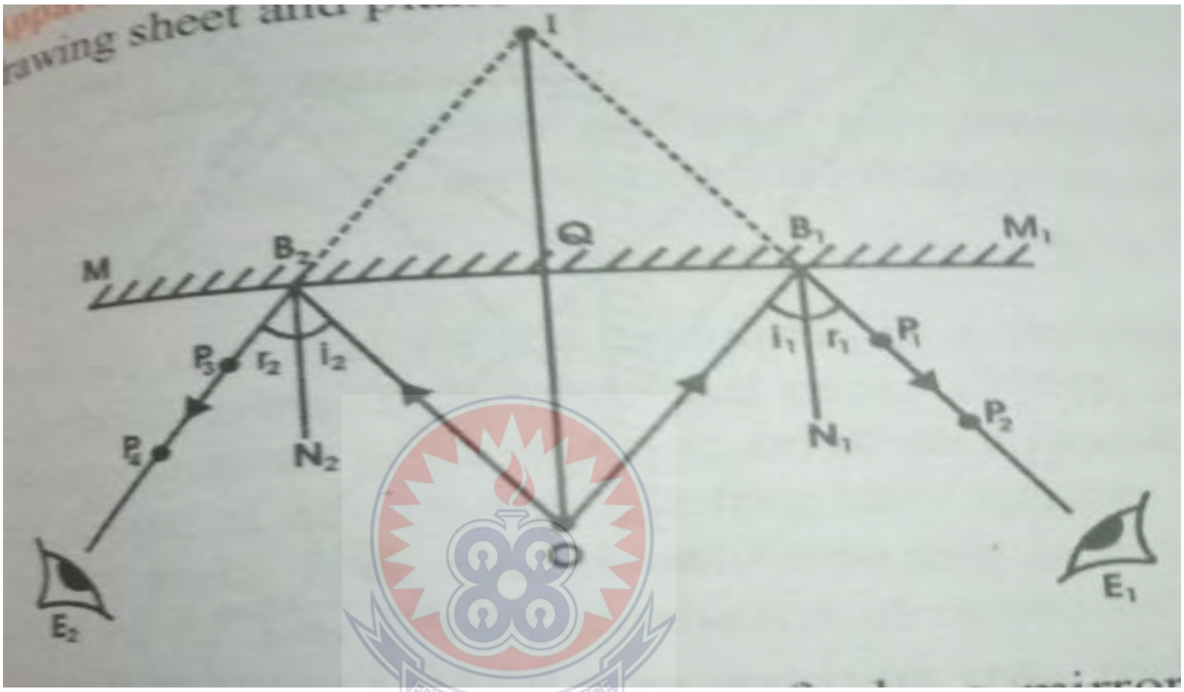
This study is conducted to assess Ghanaian senior high school students' science practical process skills. The purpose of this intervention questions is to assess senior high school physics students' science practical process skills in optics. The intervention is intended to help the researcher measure the following procession skills; measuring, inferring and data presentation skills. Information gathered through the use of this intervention will be used as a guide to prepared intervention lessons to help the physics students improve upon their practical process skills.

Information obtained using this instrument is purely for academic purposes. Students are therefore assured that any information you provide will be kept strictly confidential.

Pre-intervention Practical Questions.

Question One

Materials: You are provided with drawing board, optical pins, drawing sheet and plane mirror



Procedure:

i. A strip of plane mirror is set up vertically with silvered surface on line MM^1 drawn on a white paper on a drawing board.

ii. A pin O to serve as an object is stuck into the paper about 7-8cm from MM^1

iii. With the eye in some convenient position E_1, two pins P_1 and P_2 are stuck into the paper so as to be in a straight line with the image I of the pin O seen in the mirror.

iv. The two pins are removed and their positions, marked P_1 and P_2

v. The same procedure is carried out with the eye in at least two positions one I either side of the object.

vi. The mirror is again removed and the point P_1 and P_2 are joined to meet M and M^1 at B_1

vii. P_3 and P_4 are also joined to meet MM^1 at B_2

viii. The lines P_1 P_2 and P_3 P_4 are produced backwards behind the mirror so that they intersect at I

ix. The angle of incidence and reflection for each pair of rays are measured.

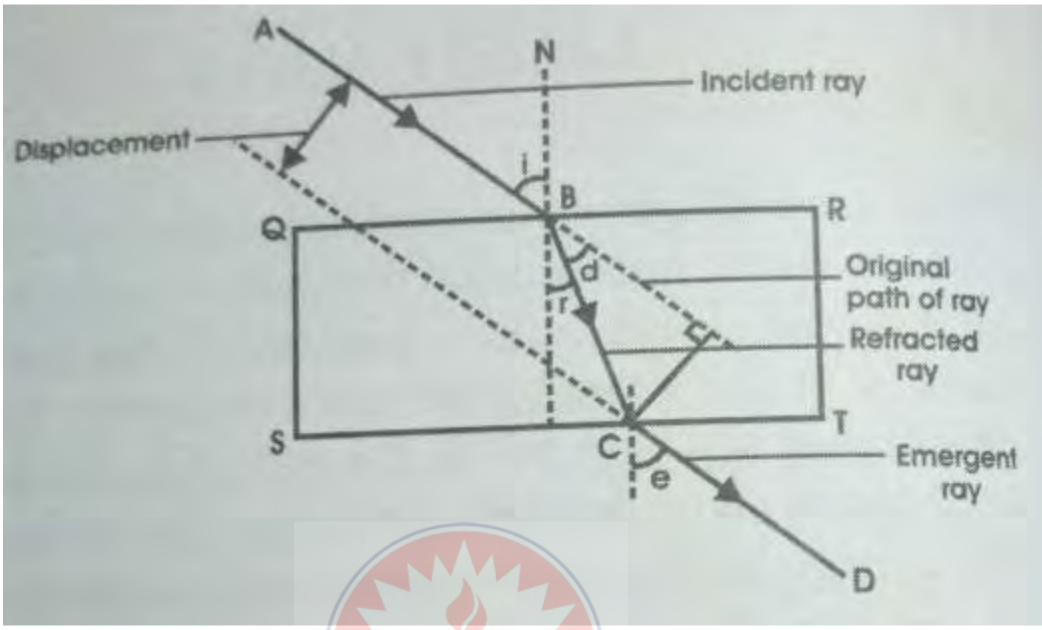
x. Repeat the experiment for four other values of angle of incidence and their corresponding values of angle of reflection

xi. Compute the difference between the angles of incidence (i) and their corresponding angles of reflection (r) and tabulate your results

xii. Briefly explain the significance of the practical and comment on the difference between i and r

Question Two

Materials: You are provided with drawing board, optical pins, drawing sheet and glass block



i. Place the rectangular glass block on a white sheet which is pinned to a drawing board.

ii. Draw the outline of the glass block QRTS

iii. Remove the glass and draw a normal to side QR at B through the outline

iv. Draw an incidence ray which makes an angle says i = 30° with the normal

v. Fix two optical pins P_1 and P_2 on the incident ray

vi. Carefully place the glass block on the outline and by looking through the side ST of the glass block, fix two pins so that they are in a straight line with P_1 and P_2

vii. Remove the glass block and the pins and draw a straight line to join P_3 and P_4 to meet the side ST at C

viii. Draw a straight line to join B and C

ix. Measure the angle the refracted ray makes with the normal

x. Repeat the experiment for i = 40°, 50°, 60°, 70° and in each case, measure the corresponding angles of refraction.

xi. Calculate sin i and sin r and tabulate your results

xii. Draw a graph of sin i on the y-axis and sin r on the

xiii. Determine the slope of the graph

xiv. Briefly explain the significance of the practical and the slope of the graph.

Marking Scheme (Scoring Rubrics)

Question One (25marks)

Measuring

i. Five complete traces showing at least incident ray, refracted ray, emergent ray and normal (5 marks)

ii. Five values of i measured and recorded in degrees to 1 d.p. (5 marks)

iii. Five values of r measured and recorded in degrees to 1 d.p. (5 marks)

iv. The difference between the angles of incidence (i) and their corresponding angles of reflection (r) computed correctly (2 marks)

Inferring

i. The significance of the practical accurately explained (3 marks)

ii. The difference between i and r accurately explained (2 marks)

Data presentation

i. Composite table showing at least i, r and (i-r) and their respective units correctly indicated (3 marks)

Question Two (40 marks)

Measuring

i. Five complete traces showing at least incident ray, refracted ray, emergent ray and normal (5 marks)
ii. Five values of i measured and recorded in degrees to 1 d.p. (5 marks)
iii. Five values of r measured and recorded in degrees to 1 d.p. (5 marks)
iv. Sin i and sin r computed correctly (5 marks)
v. Slope of the graph determined correctly (2 marks)

Inferring

i. Ability to explain the significance of the practical (3 marks)
ii. Ability to explain the significance of the slope obtained from the graph correctly (2 marks)

Data presentation

i. Composite table showing at least i, r, sin i and sin r and their respective units correctly indicated (4 marks)
ii. Axes distinguished and labelled correctly (1mark)
iii. Reasonable scale (graph must occupy at least 2/3 of the graph sheet) (1mark)
iv. Five points correctly plotted (5 marks)
v. Line of best fit (1mark)
vi. Large right-triangle for calculating slope (1mark).

APPENDIX B: INTERVENTION LESSON ON REFLECTION

SUBJECT: PHYSICS

TOPIC: REFLECTION OF LIGHT FROM PLANE AND CURVED SURFACES

SUB-TOPIC: VERIFICATION OF THE LAWS PF REFLECTION

CLASS: SHS 2 (2 SCIENCE A)

DATE: 18TH JULY, 2022.

TIME: 10:20 – 11:20

DURATION: 1 HOUR

CLASS SIZE: 45

LOCATION: PHYSICS LAB

SPECIFIC LESSON OBJECTIVE(S)

By the end of the lesson, students should be able to describe how the laws of reflection would be verified in their own words.

RELEVANT PREVIOUS KNOWLEDGE(RPK)

Students have:

1. been taught the laws of reflection in their previous lessons.
2. observed a person or objects from a driving mirror of a car.
3. been taught the rudiments of physics practical previously.

ADVANCED PREPARATION

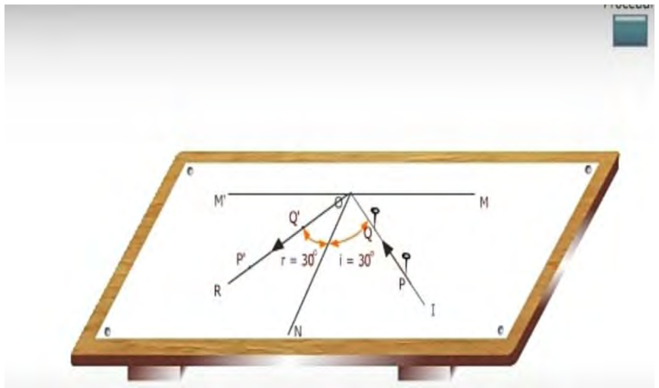
1. Download a video from Youtube to be shown during the lesson.
2. Collect a lap top and a projector to be used in showing the video.
3. Set up the lab making available the required lab apparatus for the lesson.
4. Inform students to prepare for lab work on the sub topic.
5. Read from different texts on the subject matter.

STAGE,STEP, CONTENT ITEM, ESTIMATED TIME	TLM	TEACHING AND LEARNING STRATEGY		MAIN IDEAS (CORE POINTS)
		TEACHER ACTIVITY	STUDENT ACTIVITY	
INTRODUCTION Review of RPK (3 minutes)	Teacher introduces lesson be reviewing student's RPK by asking them to state the laws of reflection	Students listen and may respond as: 1. Incidence angel equals angle of reflection 2. Incident ray, reflected ray and the normal at the point of incidence, all		

	Teacher commends students for their responses and shares lesson objective with the class	lie in the same plane. Students listen carefully and take note of lesson objective		
CONTENT DEVELOPMENT Step 1 Verification of the laws of reflection (20 minutes)		Teacher puts students into groups and distributes plane	Students from groups as instructed and	VERIFICATION OF THE LAWS OF RELECTION

	Plane mirrors, plane sheets, optical pins, safety pins, drawing board(soft surface). Laptop computer,	mirrors, plane sheets, optical pins and stapling pins to each group. Teacher guides students to ascertain which apparatus is what. Teacher commends students for their response. Teacher displays video from a projector to the class and ask students to	takes all the laboratory apparatus. Students may identify them as plane mirrors, optical pins, safety pins, plane sheets.	1. Fix a sheet of white paper on a drawing board. 2. Draw a line MM^1 on it and mark a point O at the centre of the line a draw a normal ON on MM^1. 3. Draw IO, the incident ray such that angle IOM is less than 90°. 4. Place a strip of plane mirror vertically on MM^1 with its reflecting surface facing the incident ray and the normal. 5. Fix two pins P and Q on the incident ray IO 6. Fix P^1 and Q^1 on the other side of the normal to reprent the reflected imapde of pins P and Q as observed in the mirror. 7. Remove the pins and draw a line passing through P^1 and Q^1 to represent the reflected ray.

	projector, and video from YouTube.	observe and use the video as a guide. Teacher may pause the video after every step and asks to use the apparatus provided them as and when required. Teacher goes round and see what students are doing and may offer assistance should need be.	Students watch video from the projector as a guide and follow the steps. Students carry out each step as required. Students may call teacher for help when the need arises.	8. Measure the angles of incidence and the angles of reflection. 9. Repeat for four other angles of incidence

<u>APPLICATION</u> (35 minutes)	Worksheet, Plane mirrors, plane sheets, optical pins, safety pins, drawing board (soft surface).	Teacher gives out work sheets with practical instructions to carry out in the lab, record their results in a tabular form, sketch graph and answer the questions on the worksheet.	Students work in groups to perform the practical and do independent graphing and answering of the subsequent questions.	
<u>CLOSURE</u> Review and summary of lesson (5 minutes)		Teacher reviews the lesson by asking students to briefly describe how the laws of reflection	Students may respond as stated in the core points of Step 1 above.	

		were verified in their own words. Teacher reinforces students' response where necessary and summarizes core points. Teacher gives assignment and tells student next lesson's topic	 Students pay attention and note the core points. Students listen and take note of that.	

ASSIGNEMT

1. State four characteristics of images formed by a plane mirror.
2. A fly at about eye level is 10cm in front of a plane mirror and you are behind the fly 30cm from the mirror. What is the position of the fly's image in the mirror?

REFERENCES

1. G.E.S. (2010). *The teaching syllabus for physics for senior high school.* Accra: CRDD. Pp. 9.
2. Gaur, R.K. (2008). *Basic applied physics for polytechnic students*. New Delhi: Dhanpat Rai Publications. Pp. 335.

REMARKS

Lesson was successfully delivered and taught.

APPENDIX C: INTERVENTION LESSON – REFRACTION

SUBJECT: PHYSICS

TOPIC: REFRACTION OF LIGHT

CLASS: SHS 2 (2 SCIENCE A)

DATE: 20TH JULY, 2022.

TIME: 3:00 – 4:00

DURATION: 1 HOUR

CLASS SIZE: 43

LOCATION: PHYSICS LAB

SPECIFIC LESSON OBJECTIVE(S)

By the end of the lesson, students should be able to describe refraction and verify Snell's law.

RELEVANT PREVIOUS KNOWLEDGE(RPK)

Students have:

4. been taught the laws of refraction in their previous lessons.
5. been taught the rudiments of physics practical previously.

ADVANCED PREPARATION

6. Download a video from Youtube to be shown during the lesson.
7. Collect a lap top and a projector to be used in showing the video.
8. Set up the lab making available the required lab apparatus for the lesson.
9. Inform students to prepare for lab work on the topic.
10. Read from different texts on the subject matter.

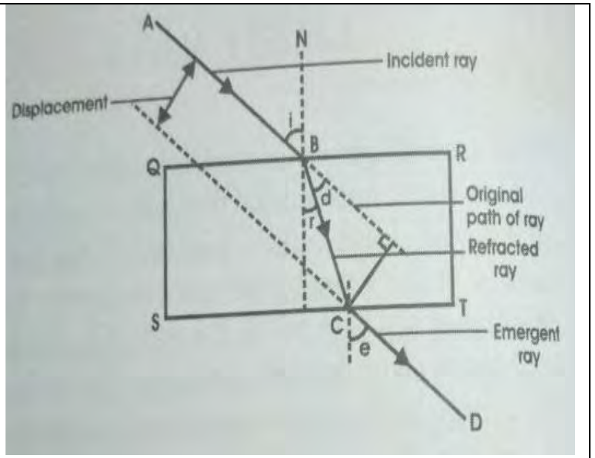
STAGE,STEP, CONTENT ITEM, ESTIMATED TIME	TLM	TEACHING AND LEARNING STRATEGY		MAIN IDEAS (CORE POINTS)
		TEACHER ACTIVITY	STUDENT ACTIVITY	
<u>INTRODUCTION</u> Review of RPK (3 minutes)	Teacher introduces lesson be reviewing student's RPK by asking them to state the laws of refraction	Students listen and may respond as: 3. The incident ray, refracted ray and the normal at the point of		

		incidence, all lie in the same plane. 4. The ratio of the sine of the angle of incidence to the angle of refraction is a constant.		
	Teacher commends students for their responses and	Students listen carefully and take note of lesson objective		

	shares lesson objective with the class			
<u>CONTENT DEVELOPMENT</u> <u>Step 1</u> Verification of the laws of refraction (20 minutes)	Rectangular glass prisms, plane sheets, optical pins, safety pins, drawing board (soft surface).	Teacher puts students into groups and distributes rectangular glass prisms, plane sheets, optical pins and stapling pins to each group.	Students from groups as instructed and takes all the laboratory apparatus.	<u>VERIFICATION OF THE SNELL'S LAW</u> 10. Place the rectangular glass block on a white sheet which is pinned to a drawing board. 11. Draw the outline of the glass block QRTS 12. Remove the glass and draw a normal to side QR at B through the outline

		Teacher guides students to ascertain which apparatus is what. Teacher commends students for their response. Teacher displays video from a	Students may identify them as rectangular glass prisms, optical pins, safety pins, plane sheets. Students watch video from the projector as a	13. Draw an incidence ray which makes an angle says i = 30° with the normal 14. Fix two optical pins P_1 and P_2 on the incident ray 15. Carefully place the glass block on the outline and by looking through the side ST of the glass block, fix two pins so that they are in a straight line with P_1 and P_2 16. Remove the glass block and the pins and draw a straight line to join P_3 and P_4 to meet the side ST at C 17. Draw a straight line to join B and C

	Laptop computer, projector, and video from YouTube.	projector to the class and ask students to observe and use the video as a guide. Teacher may pause the video after every step and asks to use the apparatus provided them as and when required.	guide and follow the steps. Students carry out each step as required. Students may call teacher for help	18. Measure the angle the refracted ray makes with the normal 19. Repeat the experiment for i = 40°, 50°, 60°, 70° and in each case, measure the corresponding angles of refraction. 20. Calculate sin i and sin r and tabulate your results 21. Draw a graph of sin i on the y-axis and sin r on the 22. Determine the slope of the graph 23. Briefly explain the significance of the practical and the slope of the graph.

		Teacher goes round and see what students are doing and may offer assistance should need be.	when the need arises.	
<u>APPLICATION</u> (35 minutes)	Worksheet with tasks.	Teacher gives out work sheets with practical instructions to carry out in the lab, record their results in a tabular	Students work in groups to perform the practical and do independent graphing and	

		form, sketch graph and answer the questions on the worksheet.	answering of the subsequent questions.	
<u>CLOSURE</u> Review and summary of lesson (5 minutes)		Teacher reviews the lesson by asking students to briefly describe how the Snell's law was verified in their own words.	Students may respond as stated in the core points of Step 1 above.	

		Teacher reinforces students' response where necessary and summarizes core points. Teacher gives assignment and tells student next lesson's topic	Students pay attention and note the core points. Students listen and take note of that.	

ASSIGNMENT

3. State two (2) conditions for total internal reflection would occur.
4. A ray of light id incident at 60° in air to a glass plane surface. Find the angle of refraction. (${}_an_g = 1.5$)

REFERENCES

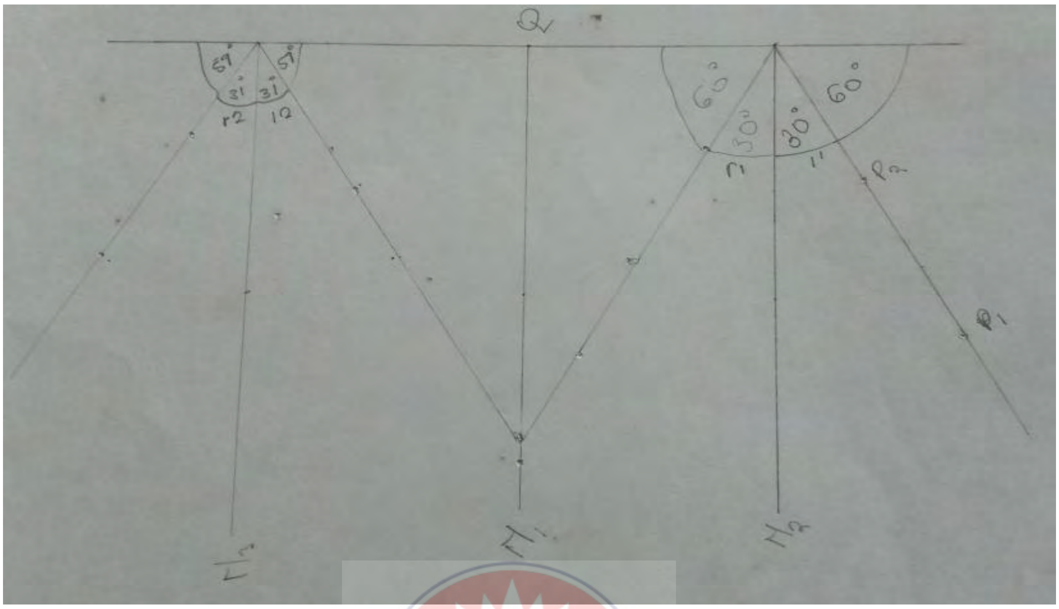
3. G.E.S. (2010). *The teaching syllabus for physics for senior high school.* Accra: CRDD. Pp. 9.
4. Gaur, R.K. (2008). *Basic applied physics for polytechnic students*. New Delhi: Dhanpat Rai Publications. Pp. 335.

REMARKS

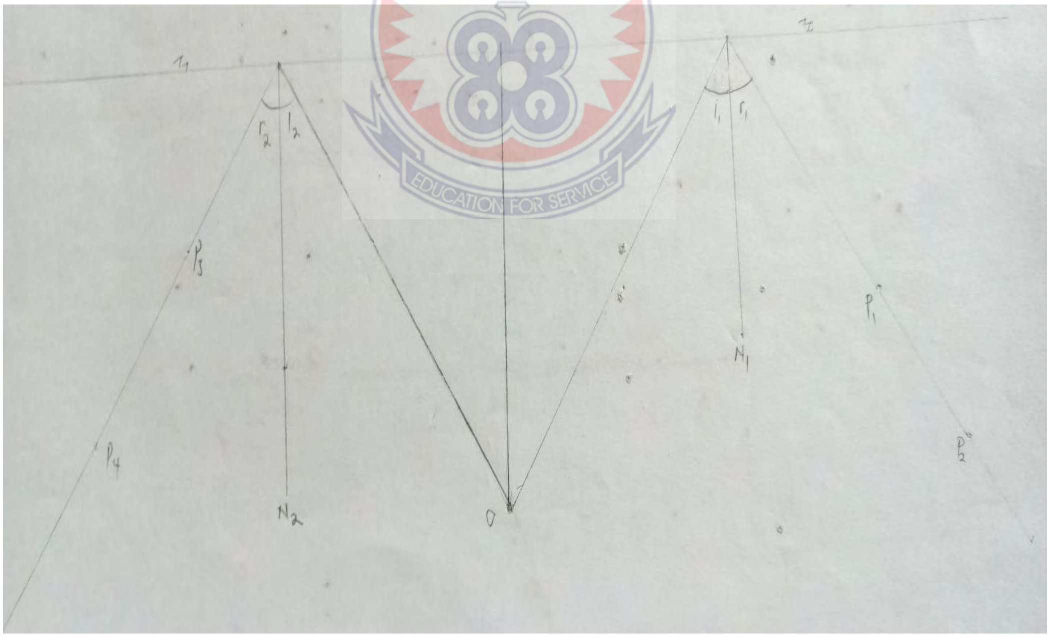
Lesson was successfully delivered and taught.

APPENDIX D: SAMPLE OF STUDENTS' RESPONSES

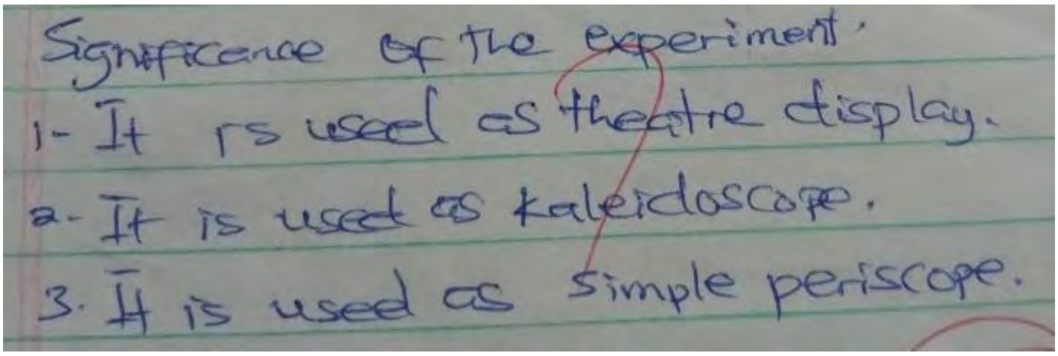
a. Sample of students' response



b. Sample of students' response

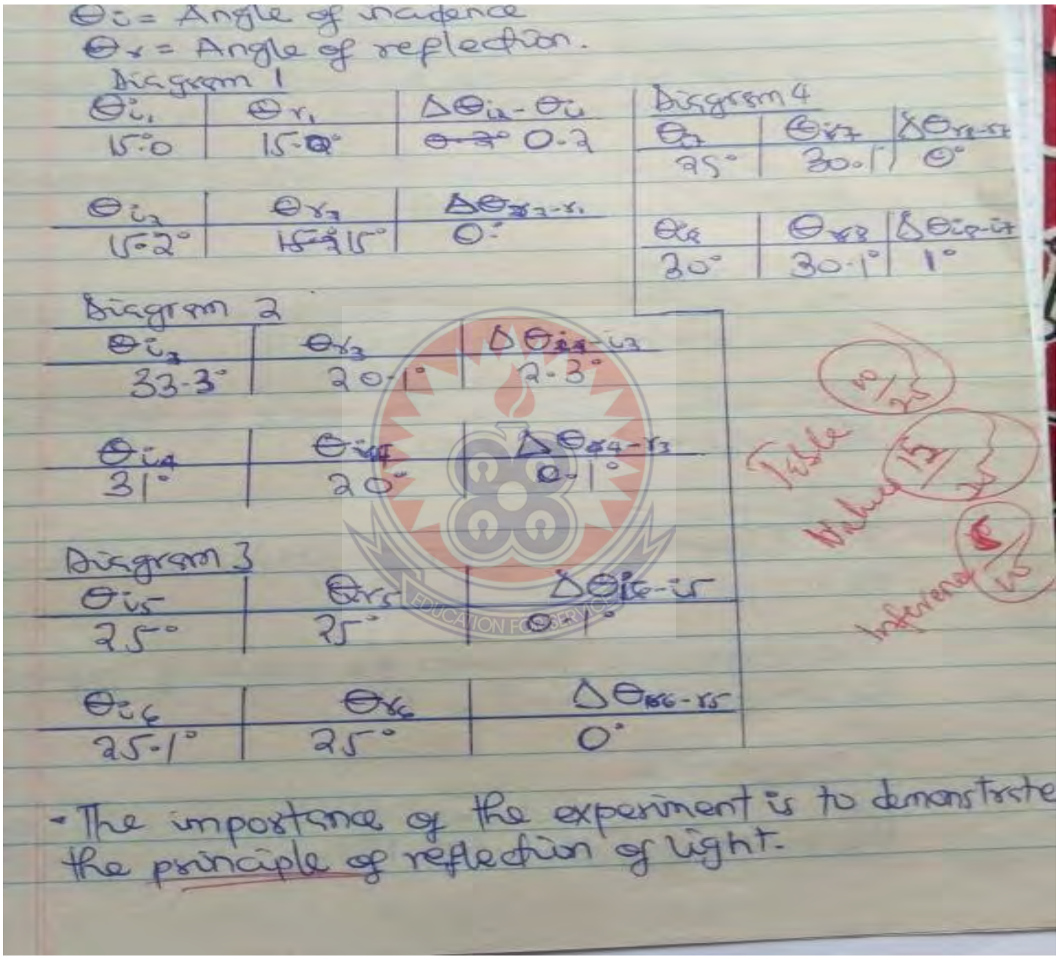


c. **Sample of students' response**



Significance of the experiment.
1- It is used as theatre display.
2- It is used as kaleidoscope.
3. It is used as simple periscope.

d. **Sample of students' response**



θ_i = Angle of incidence
θ_r = Angle of reflection.

Diagram 1

θ_{i_1}	θ_{r_1}	$\Delta\theta_{i_1} - \theta_{i}$
15.0	15.0°	0.2

θ_{i_2}	θ_{r_2}	$\Delta\theta_{r_2 - r_1}$
15.2°	15°	0°

Diagram 2

θ_{i_3}	θ_{r_3}	$\Delta\theta_{i_4 - i_3}$
33.3°	20.1°	2.3°

θ_{i_4}	θ_{r_4}	$\Delta\theta_{r_4 - r_3}$
31°	20°	0.1°

Diagram 3

θ_{i_5}	θ_{r_5}	$\Delta\theta_{i_6 - i_5}$
25.0°	25°	0.1°

θ_{i_6}	θ_{r_6}	$\Delta\theta_{r_6 - r_5}$
25.1°	25°	0°

Diagram 4

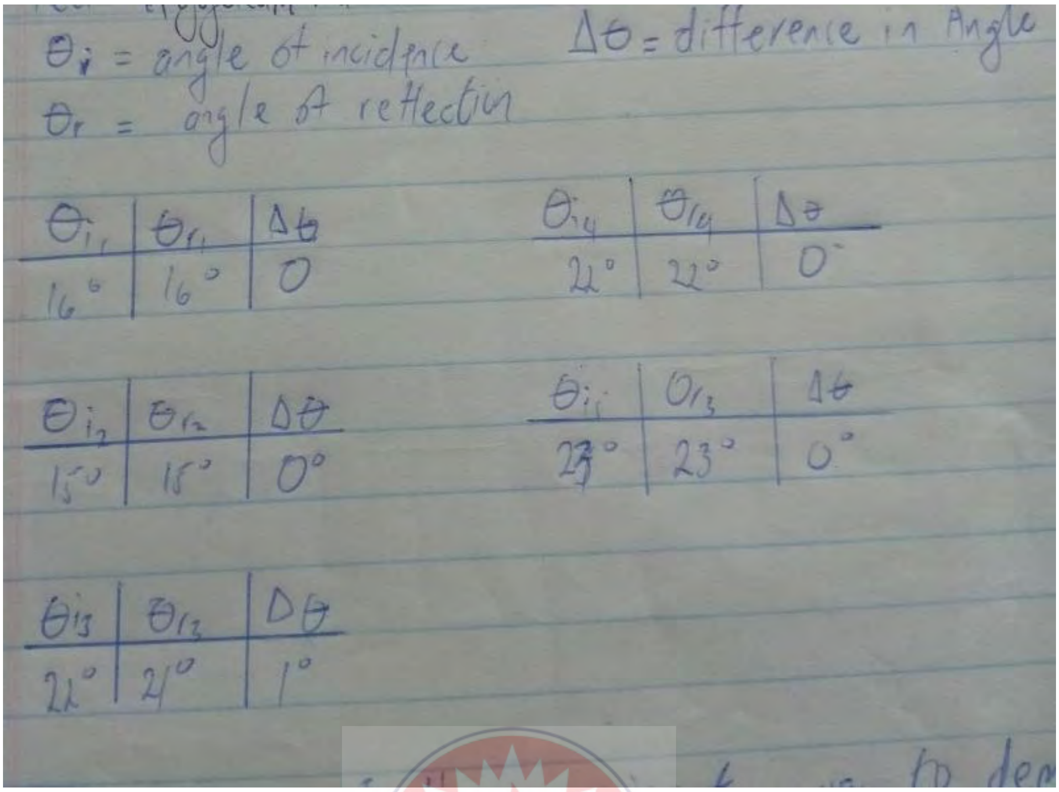
θ_{i_7}	θ_{r_7}	$\Delta\theta_{r_8 - r_7}$
25°	30.1°	0°

θ_{i_8}	θ_{r_8}	$\Delta\theta_{i_8 - i_7}$
30°	30.1°	1°

10/25
Table
Values 15/25
Inference

- The importance of the experiment is to demonstrate the principle of reflection of light.

e. Sample students' response



θ_i = angle of incidence

θ_r = angle of reflection

$\Delta\theta$ = difference in Angle

θ_{i_1}	θ_{r_1}	$\Delta\theta$
16°	16°	0

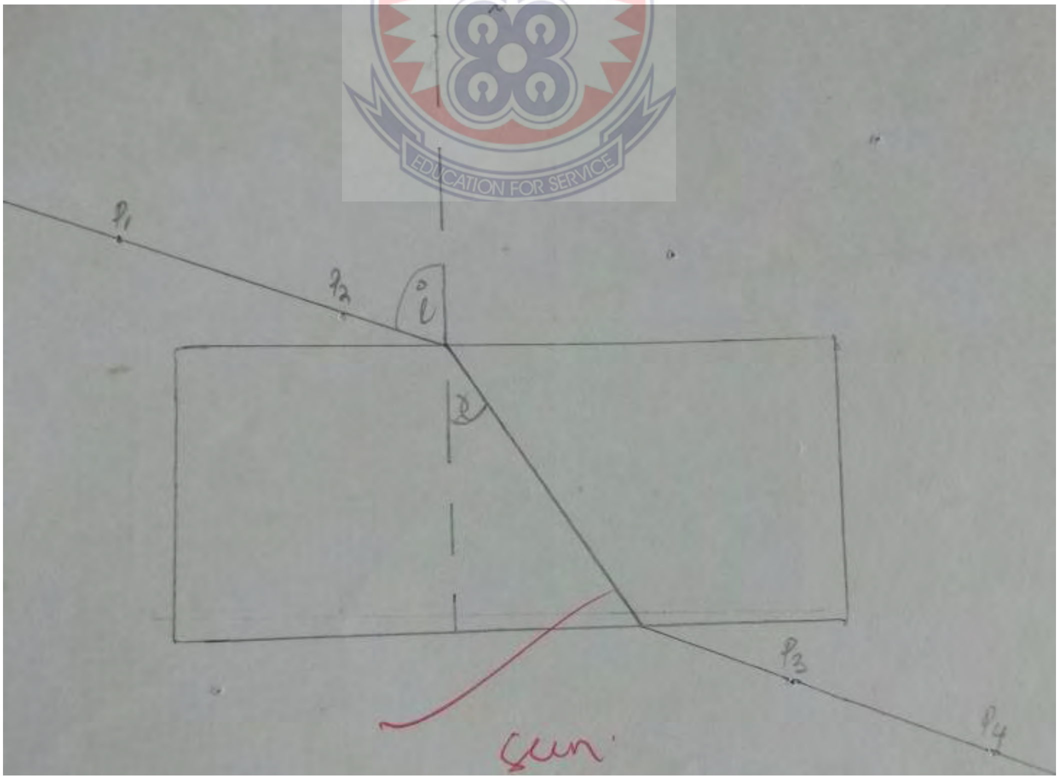
θ_{i_4}	θ_{r_4}	$\Delta\theta$
22°	22°	0°

θ_{i_2}	θ_{r_2}	$\Delta\theta$
15°	15°	0°

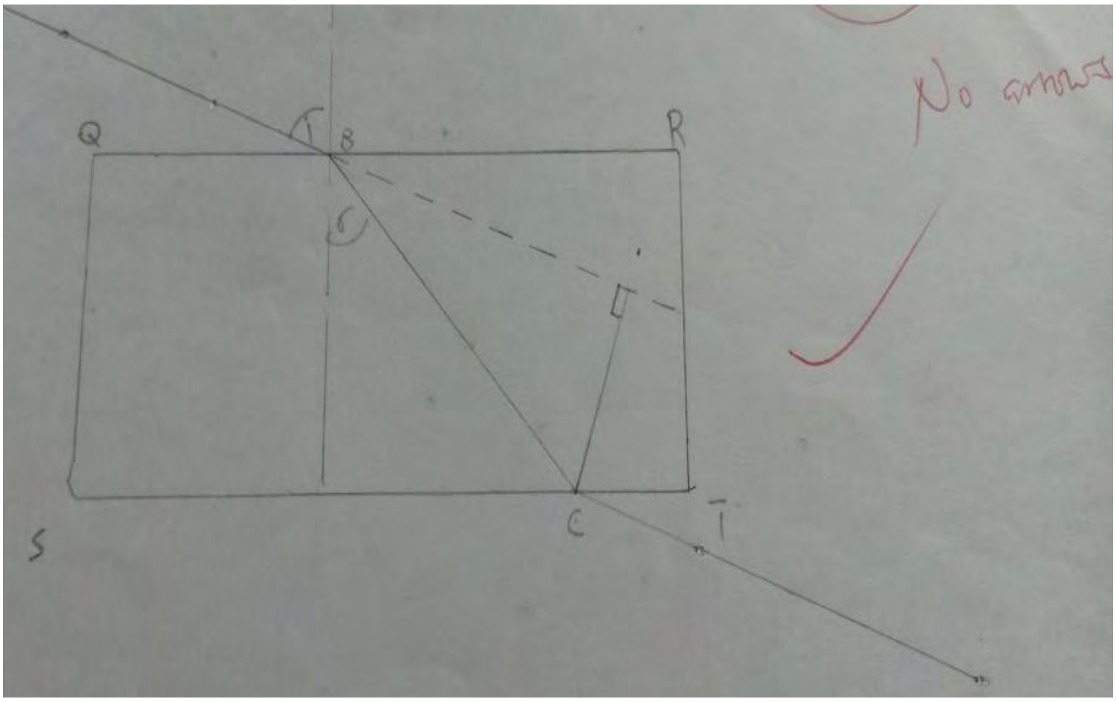
θ_{i_5}	θ_{r_5}	$\Delta\theta$
23°	23°	0°

θ_{i_3}	θ_{r_3}	$\Delta\theta$
22°	21°	1°

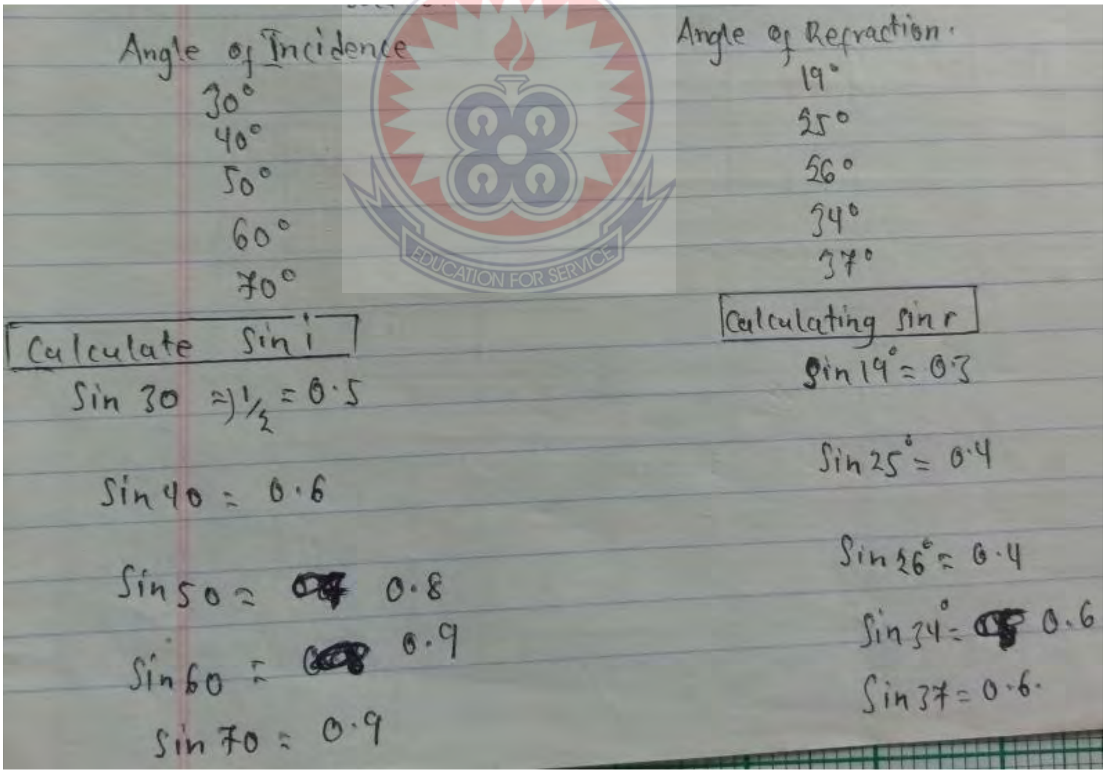
f. Sample of students' response



g. Sample of students' response



h. Sample of students' response



i. **Sample of students' response**

j. **Sample of students' response**

Angle Of Incidence i/°	sin i	Angle Of Refraction r/°	sin r
30.0°	0.500	16.0°	0.276
40.0°	0.643	25.0°	0.423
50.0°	0.766	30.0°	0.500
60.0°	0.866	45.0°	0.707
70.0°	0.940	55.0°	0.819

$\frac{0.423 - 0.276}{0.643 - 0.500}$

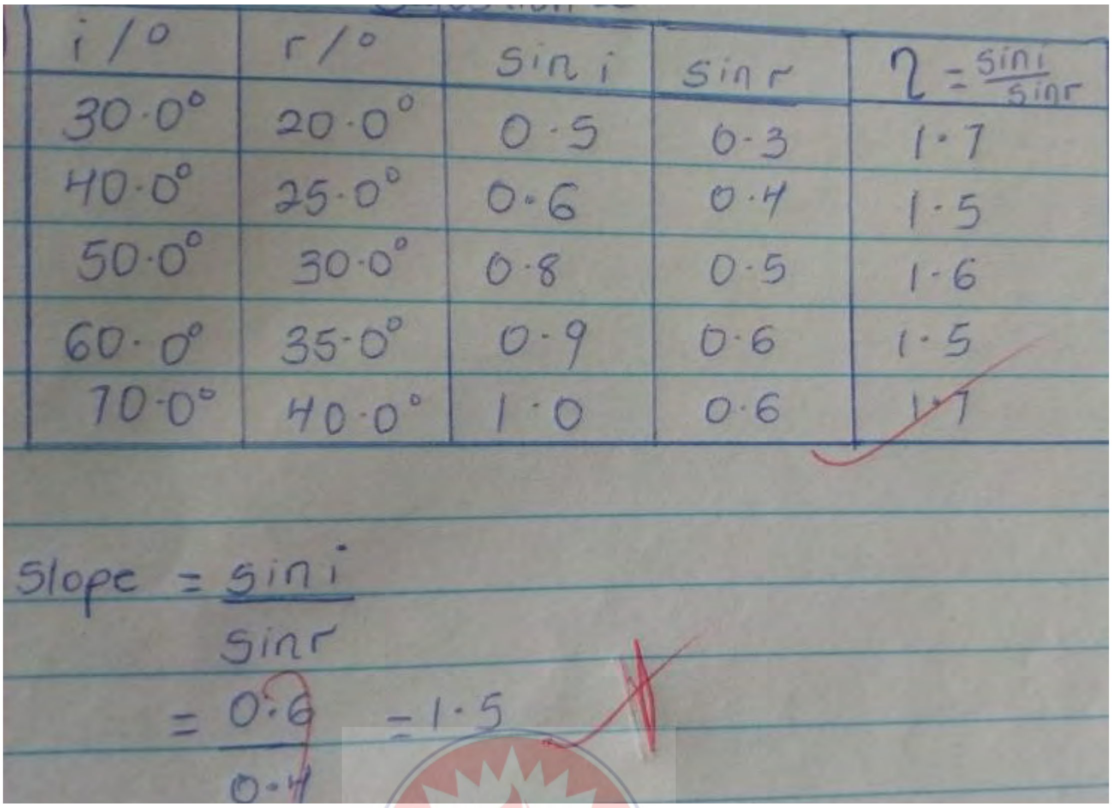
02

(xiii) Slope m, $= \frac{0.866 - 0.766}{0.707 - 0.500}$

m = 0.48

Slope = 0.5

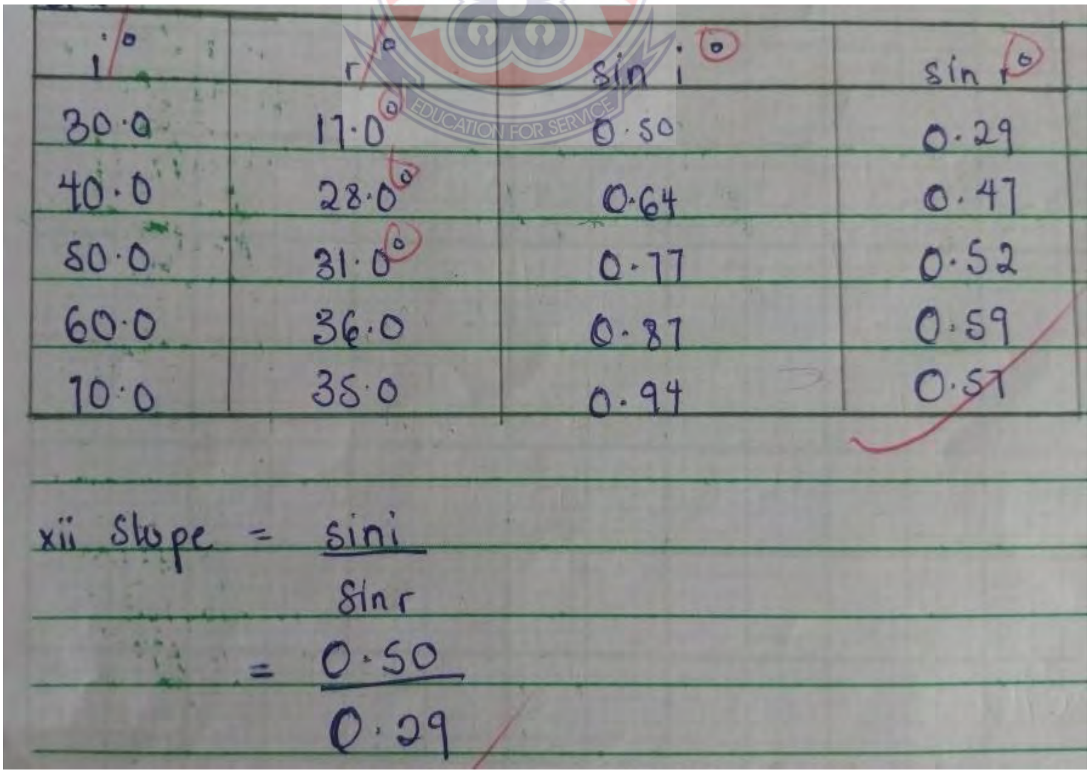
k. Sample of students' response



$i/°$	$r/°$	$\sin i$	$\sin r$	$\eta = \frac{\sin i}{\sin r}$
30.0°	20.0°	0.5	0.3	1.7
40.0°	25.0°	0.6	0.4	1.5
50.0°	30.0°	0.8	0.5	1.6
60.0°	35.0°	0.9	0.6	1.5
70.0°	40.0°	1.0	0.6	1.7

$$\text{Slope} = \frac{\sin i}{\sin r} = \frac{0.6}{0.4} = 1.5$$

l. Sample of students' response



$i/°$	$r/°$	$\sin i°$	$\sin r°$
30.0	17.0°	0.50	0.29
40.0	28.0°	0.64	0.47
50.0	31.0°	0.77	0.52
60.0	36.0	0.87	0.59
70.0	35.0	0.94	0.57

xii $\text{Slope} = \frac{\sin i}{\sin r} = \frac{0.50}{0.29}$

m. Sample of students' response

$i°$	$r°$	sin i	sin r
30.0	20.0	0.5	0.34
40.0	26.0	0.64	0.44
50.0	30.7	0.77	0.51
60.0	40	0.87	0.64
70.0	44.0	0.94	0.69

$$\cancel{\frac{0.94 - 0.87}{0.69 - 0.64} = \frac{7}{5} = 1.4}$$

Slope of graph $s = \frac{\sin i}{\sin r} = \frac{0.5}{0.34} = 1.47 =$

APPENDIX E: SPPS RESULTS

Paired Samples Statistics (Reflection Task- Data Presentation)

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre-intervention test scores	1.62	45	.490	.073
	Post-intervention test scores	1.84	45	.562	.084

Paired Samples Test (Reflection Task-Data Presentation

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Preinterventiontest - Postinterventionscores	-.222	.704	.105	-.434	-.011	-2.119	44	.040

Paired Samples Statistics (Reflection Task-Measuring)

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Preinterventiontest	8.24	45	2.414	.360
	Postinterventionscores	14.33	45	1.087	.162

Paired Samples Test (ReflectionTask- Measuring)

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
Pair 1	Preinterventiontest - Postinterventionscores	-6.089	2.539	.378	-6.852	-5.326	-16.087	44	.000

Paired Samples Statistics Reflection Task-Infering

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Preinterventiontest	2.02	45	1.485	.221
	Postinterventionscores	3.22	45	1.241	.185

Paired Samples Test (Reflection Task Infering)

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	95% Confidence Interval of the Difference Upper			
Pair 1	Preinterventiontest - Postinterventionscores	-1.200	1.714	.255	-1.715	-.685	-4.698	44	.000

Paired Samples Statistics (Refraction Task-Data Presentation)

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Preinterventiontest	8.76	45	1.798	.268
	Post intervention scores	8.78	45	1.941	.289

Paired Samples Test (Refraction Task-Data Presentation)

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1	Preinterventiontest - Postinterventionscores	-.022	2.435	.363	-.754	.709	-.061	44	.951

Paired Samples Statistics(Refraction Task-Measuring)

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre intervention test	14.98	45	1.725	.257
	tervention scores	17.16	45	1.507	.225

Paired Samples Test(Refraction Task- Measuring)

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Preinterventiontest - Postinterventionscores	-2.178	2.003	.299	-2.780	-1.576	-7.293	44	.000

Paired Samples Statistics(Refraction Task-Inferring)

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre intervention test	2.27	45	1.587	.237
	Post intervention scores	2.47	45	1.408	.210

Paired Samples Test (Refraction Task-Infering)

		Paired Differences					t	df	Sig. (2-tailed)
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper			
Pair 1	Preinterventiontest - Postinterventionscores	-.200	2.052	.306	-.816	.416	-.654	44	.517

Paired Samples Statistics(Reflection Task)

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre intervention test	11.89	45	3.472	.518
	Post intervention scores	19.40	45	1.982	.295

Paired Samples Test (Reflection Task)

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Preinterventiontest - Postinterventionscores	-7.511	3.782	.564	-8.647	-6.375	-13.324	44	.000

Paired Samples Statistics(Refraction)

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pre intervention test	26.00	45	3.497	.521
	Post intervention scores	28.40	45	3.816	.569

Paired Samples Test(Refraction)

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Preinterventiontest - Postinterventionscores	-2.400	4.644	.692	-3.795	-1.005	-3.467	44	.001