UNIVERSITY OF CAPE COAST

ASSESSMENT OF GHANAIAN SENIOR HIGH SCHOOL STUDENTS' SCIENCE PROCESS SKILLS IN OPTICS

BY

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DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this University or elsewhere.

Candidate's Signature: .... Date: 30/04/2018

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Supervisors' Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

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ABSTRACT

This study was undertaken using performance-based instruments to assess science process skills of planning, performing and reasoning of senior high school physics students. The study had a sample of 225 male and female students from seven schools (i.e. single sex male; single sex female and mixed categories) offering general science in the Cape Coast Metropolis of the Central Region of Ghana. The study examined the levels of proficiencies of skills exhibited by students in the process skills of planning, performing and reasoning in Reflection and Refraction in Optics. The researcher adapted the instruments used in this study (Ossei Anto, 1996). The tasks were in two groups: Tasks A and Tasks B, each of three tasks of planning, performing and reasoning. The researcher scored the students tasks booklets. Quantitative data was collected using performance assessment technique of psychometric testing. Considering the three science process skills of planning, performing and reasoning, the most proficient skill exhibited by the students was reasoning, followed by planning and the least was performing tasks. With gender, the female elective physics students demonstrated the highest level of proficiency in the science process skills across all the tasks compared to males. With type of school, single sex female elective physics students exhibited the highest level of proficiency across all the tasks, followed by single sex boys, with mixed schools being least proficient. In the light of the findings of this study, a number of recommends were made. One of them is that, students in elective physics should be motivated to develop high proficiencies in laboratory activities using hands-on and minds-on skills of planning, performing and reasoning.

KEY WORDS

Scientific inquiry

Science process skills

Reflection and Refraction in Optics

Performance assessment

Scoring rubrics

Constructivist view of teaching and learning

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DEDICATION

To my sweet wife, Dr (Mrs) Sherry Ama Mawuko Johnson – School of Veterinary Medicine, University of Ghana, Legon.

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LIST OF ABBREVIATIONS

NRC	National Research Council (U.S.A)
CRDD	Curriculum Research and Development Division
SAPA	Science A Process Approach
AAAS	American Association for the Advancement of Science
WAEC	West African Examinations Council
U.S.A.	United States of America
NSTA	National Science Teachers Association
CDC	Curriculum Development Council (Hong Kong)
HKEAA	Hong Kong Examinations and Assessment Authority
NSF	National Science Foundation (U.S.A)
NAP	National Academy Press

CHAPTER ONE

INTRODUCTION

This study assessed 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 employed the constructivist theory of learning which posits that students can construct their own knowledge when the needed environment is created (Driver & Bell, 1986).

Background to the Study

Education is the starting point for individuals to build themselves for opportunities in the future. Education is sharing, learning and growing up together with others. Through education, we can learn to take better/proper care of our world; treat it respectfully and use wisely the resources it offers us. Education concerns itself with learning at all levels, from basic and secondary school through adult education, and provides knowledge and training for basic skills development, civic awareness, community education, education for special populations, treatment and training of the youth. Education when properly carried out by teachers and students leads to empowerment.

Currently, technological and scientific revolution is one of modern human history. Hence acquaintance with science education and technology as elements of human culture should be the focus of every individual, irrespective of their occupational needs.

The challenge confronting science education worldwide is how to prepare today's youth for tomorrow's world. Schooling can no longer function in isolation from the realities of present-day living. Schooling must go beyond the laboratories into the public spheres and experiences of more than information giving and absorption. Students must actively engage in the process of learning so that they can apply their observations, knowledge, and interpretations to the world around them (Cohen, Manion & Morrison, 2006). According to Ofori-Amanfo (2001), the benefits of science are not fully utilized by society because the progress of science is controlled by individuals and groups who have an inaccurate understanding of the nature of science.

Science as a matter of fact plays a major role in the quality of life of a nation; this is because science is both a process and a product, hence when the process is not well done the citizenry will not get the prospects. We can see around us plastics thrown into drains, and other waste products which mar the beauty of the environment. This may lead to malaria, cholera, fatalities and therefore lead to reduction in productivity. Used plastics when collected and properly handled can be recycled for other uses. According to Kelly (2007) the goals of science are to assist the students to develop the following:

i. The mindset which can cope with the problems of living in a fast changing world;

ii. The skills of critical/logical thinking, designing and performing tasks to their highest capability;

iii. Enquiry and development in experimental skills;

iv. Problem solving ability;

v. Acquire the skills of using knowledge constructively.

It must be noted that most of the instructional strategies used in our science classrooms are usually teacher-centered and hence make students passive, only at the receiving end of the teaching and learning process which is normally assumed that students do not have anything to offer when it comes to the science class. Often science subjects are taught without focusing on the hands-on, practical/laboratory skills; at best teachers use demonstrations instead (Chamgeigwo, Wambugu & Wachanga, 2011). Most of instructional time is used for listening to lectures from teachers and copying notes, either from the board or dictated by teachers. Sometimes teachers read from textbooks directly to students. Examples of exercises are normally taken directly from the textbooks without any modification.

Buabeng and Ntow (2010) identified the teacher factor to be one of the numerous reasons for students' negative response to physics in Ghana. In their study, they explained that most of the students reported that their reduced interest in physics, as a subject, was mainly due to the way and manner in which the subject was presented to them.

According to Wieman and Perkins (2005) physics education is going through crisis. This is an international trend and its basic features are: Students' disinterest in the sciences, unpopularity of physics, and very low degree of factual knowledge and experimental skills.

Most students in Ghanaian science classes (especially physics) go through the course without the proper hands-on laboratory activities at the appropriate times. There is the need for students to go through vigorous practical training and activities to become the future competent scientists. The progress and development, scientifically and technologically, of Ghana is directly linked to how well we train our qualified scientists, technologists and engineers are trained.

The importance of science education cannot be over emphasized and has over the years been expressed by governments and nations. Science is important to our young people not only for science knowledge, but also for the life process skills that can be gained through science study; thus enabling students to develop into adults who are able to take informed and responsible actions when engaging and reflecting upon different ideas, opinions and beliefs or values. In addition science is a valid vehicle for delivering healthy and safety awareness in students.

Science is a process of inquiring and investigation, which is a way of thinking and action, not a body of knowledge to be acquired by memorizing facts and principles (Ellen, 1995). Science education reform documents of Ministry of Education (2007) emphasize the importance of inquiry experiences for young students. This means that teachers must be prepared with the knowledge, skills, and habits of thinking to mentor their students through authentic investigations. The role of process skills in the development of understanding is crucial. If these skills are not well developed, and teachers do not check to be sure that students they teach have acquired proficiency levels high enough, learning with understanding will be hampered. Thus the development of scientific process skills has to be a major goal of science education. It is important to understand that applying what we know about child development contributes to science teaching. One of the main reasons for doing science is that, it is fun and most children like science; example of an aspect of science is field trip. Who dislike field trips? The development of the high level thinking skills that science can hopefully produce in students can be used in the wider work place in later life of the pupil or student. It is also true that after school, many students will never see most of the laboratory equipment again. There are some scientific techniques they can acquire and if they have lots of practice with equipment and materials, they may as well get better at such skills as planning and observation. These are aspects of learning that would be valuable after formal schooling is over.

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 addition to the above mentioned, the focus is on skills development and developing the students' understanding of the nature of science. This puts teachers in a very challenging situation, since some of them will need training, re-training, through refresher courses and learning as well as unlearning certain things all over again. The changes in the science curriculum at the moment are fundamentally due to attention placed on how science and society interacts, rather than pure science for science's sake. Science is for everybody. This statement highlights the importance of science education to society and compulsory science education curriculum at both the basic and secondary (senior high school) levels in Ghana's educational system. 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'. 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. 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; Lee, 1999; Ossei-Anto, 1996). Laboratory instruction has long had a significant role in science education and literature pointed out the gains of students from engaging in science laboratory activities (Tobin, 1990). Process skills development enables students to learn to:

(a) identify and define pertinent variable
(b) interpret, transform and analyze data,
(c) plan and design an experiment,
(d) formulate hypotheses, and
(e) draw conclusions.

An important role of science educators is to assist students develop thinking skills of scientists of which process skills are vital. Based on this, Okey (1972) is of the view that the main goal of science education is to assist students to acquire and process information meaningfully. He again indicated that science process skills that go beyond the acquisition of facts is highly valued because they approximate how students will use knowledge in and out of school situation.

As defined by Science - A Process Approach (S-APA) (American Association for the Assessment of Science [AAAS], 1993), science process skills are supposed to be broadly transferable, appropriate to many science disciplines, and reflective of the true behaviour of scientists. S-APA divided 13 skills into two types - basic and integrated. The basic science processes are observing, classifying, communicating, measuring, using space/inferring, and predicting. These skills provide a foundation for learning the more complex integrated skills – controlling variables, interpreting data, formulating hypotheses, defining operationally and experimenting. Without a good amount of practice, expectations of skills mastery will be quite unrealistic.

The assessment process consists of both measurement procedures (i.e. tests) and non-measurement procedure (i.e., informal observation) for describing changes in student performance as well as value judgement concerning the desired changes. When guided by a set of general principles, the process of assessment could be effective.

According to Stiggins and Bridgeford (1982) performance assessment is defined as:

> "Performance assessment is defined as a systematic attempt to measure a learner's ability to use previously acquired knowledge in solving problems or completing specific tasks. In performance assessment, real life or simulated assessment exercises are used to elicit original responses which are directly observed and rated by a qualified judge" (Stiggins & Bridgeford, 1982, p.1).

(Knutton, 1994, p. 155) shares some of the advantages offered by the integration of performance assessment in science within the British education system:

i. The elimination of chance failure in one off situation.

ii. Providing a richer and more varied experience of practical work.

iii. Enabling a wider range of skills to be assessed.

iv. Greater reliability (teachers are in the best position to assess students' practical skills because they see them over an extended period of time.

v. Permitting theory and practice to be more closely linked.

vi. Becoming an integral part of the teaching and learning process (formative rather than just summative)

Laboratory assessment of students' skills has been in use for a long time. Kruglak as cited by Ossei-Anto (1996) adopted the laboratory examination method for a physics classes at University of Minnesota. Programmes were put in place to develop science process skills; one of these programmes, Science – A Process Approach (SAPA), was designed to emphasize the laboratory method of instruction, and focused on ways of developing basic skills in the process of science. SAPA was developed by the American Association for the Advancement of Science (AAAS), a Commission on Science Education, with the common belief that science was best taught through inquiry (Lee, 1999).

Science is a human endeavour in which knowledge about the universe and its parts is sought, organized, constructed, and reconstructed through scientific methods to seek answers and solve problems – a disciplined form of human curiosity that constitutes the driving force of science. Through inquiry experiences, students do not only learn about concepts, but they also learn to ask reasonable questions and obtain answers that sometimes generate more questions. Science instruction for students at the senior high level is known to be more effective when concrete experiences establish the basis for the construction of scientific concepts. It is found out that "hands-on" laboratory investigations guided by appropriate questions also help concept formation.

Optics is a branch of physics which requires students to use process skills in order to understand all the basic concepts in it. Optics is a branch of physics which deals with the study of nature, propagation and behaviour of electromagnetic properties of light Avison (1989). Unfortunately, it has been observed that students are not interested in optics and hence are not able to answer basic questions (Cornah, 2016). This could be because students are poorly equipped with the process skills needed to solve questions in optics. As a result, it can be concluded that there exist a gap between the knowledge gathered through books and its applicability in real work (Byzee, Trowbridge & Powell, 2008). Therefore, in order for students to come to terms with concepts in optics, they should be made to engage in hands-on and minds-on activities. There appear to be very little research, if any, on how students' process skills have been assessed. It is therefore important to undertake a study with the prime aim of assessing students' process skills in optics since this could help teachers develop students' interest in optics.

The Context of the Study

In Ghana, the educational system is categorized into Tertiary and Pre-Tertiary levels. The pre-tertiary level is governed by the Ghana Education Service and it also has two divisions namely: first cycle and second cycle while the National Council for Tertiary Education (NCTE) takes charge of the tertiary level.

At the first cycle of the pre-tertiary educational level, we have Kindergarten, Lower primary, Upper primary and Junior High School. The lower primary level takes at least seven subjects, namely- Natural Science, Creative Arts, ICT, RME, Mathematics, Language and Literacy (English and Ghanaian Languages). However, the upper primary takes Citizenship Education in addition to the seven subjects with Natural Science being substituted by Integrated Science. Though some teachers read special courses during their training, they are expected to teach all subjects when stationed at the lower or upper primary levels. But in JHS, teachers are normally given their area of specialization. The subjects taught at the JHS level are not so much different from the upper primary with the exception of Social Studies which takes the place of Citizenship Education.

The final part of the Pre-tertiary education is the second cycle which comprises of the general SHS, and the Technical Schools. There are different subject combinations at this level. Notwithstanding, there are certain subjects which are compulsory for all students and they are called core subjects. The core subjects are English Language, Core Mathematics, Social Studies and Integrated Science. The differences, therefore, are brought about when students select their optional or elective subjects.

Broadly, the SHS boasts of the following subject combination (courses): General Science, General Arts, Visual Arts, Agricultural Science, Home Science, Business and Technical Subjects. With regards to General Science, majority of the students take Physics, Chemistry, Biology and

Elective Mathematics while a few students may take Geography as one of their elective subjects.

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. 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). This could be attributed to the poor performance of science students in elective physics at the SHS level in School Certificate examinations

It is important to train students to be equipped with science process skills and scientific thinking. This approach to events should not be overlooked in any educational enterprise (Archenhold, 1983; Ossei-Anto, 1996; Swain, 1989). 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). However, students do not show satisfactory competencies in the development of science process skills, such as designing experiments, analyzing data and drawing conclusions during laboratory or practical sessions (Ossei-Anto, 1996).

There are several issues raised by West African Examination Council's Chief Examiners reports on various weakness of students' science process skills (WAEC, 2011; WAEC, 2012; WAEC, 2013). Research works on teaching physics have shown that students have difficulties in learning optics because it is one of the subjects which many students have prevalent alternative conceptions (Aboagye, 2009). This could be due to the fact that teachers and students do not possess the requisite science process skills needed to confront problems in optics. It appears research has not been able to show how science process skills can be assessed effectively in order to yield the appropriate results. This current study therefore assessed the proficiency levels (planning, performing and reasoning) of science process skills of refraction and reflection in optics at the senior high school level.

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 optics (reflection and refraction). Specifically, the study aimed at assessing the proficiency levels of students' process skills in planning, performing and reasoning on the concepts of reflection and refraction in optics. It further compared the proficiency levels of male and female students across the schools used and also across school-type (i.e., boys, girls and mixed schools).

Research Questions

1. What are the perfomance levels of physics students engaged in science process skills of planning, performing and reasoning in refraction and reflection?
2. a. What are students' appropriate and inappropriate responses for planning, performing and reasoning in refraction?
   b. What are students' appropriate and inappropriate responses for planning, performing and reasoning in reflection?

Hypotheses

The following six hypotheses guided the study and were tested at .05 level of significance:

H_{O1}: There is no statistically significant difference in the proficiency levels in physics students' science process skills (planning, performing and reasoning) in refraction.

H_{A1}: There is statistically significant difference in the proficiency levels of physics students' in science process skills (planning, performing and reasoning) in refraction.

H_{O2}: There is no statistically significant difference in the proficiency levels of physics students' in science process skills (planning, performing and reasoning) in reflection.

H_{A2}: There is statistically significant difference in the proficiency levels of physics students' in science process skills (planning, performing and reasoning) in reflection.

H_{O3}: There is no statistically significant difference in the proficiency levels of male and female physics students in science process skills (planning, performing and reasoning) in refraction.

H_{A3}: There is statistically significant difference in the proficiency levels of male and female physics students in science process skills (planning, performing and reasoning) in refraction.

H_{O4}: There is no statistically significant difference in the proficiency levels of male and female physics students in science process skills (planning, performing and reasoning) in reflection.

H_{A4}: There is statistically significant difference is the proficiency levels of male and female physics students in science process skills (planning, performing and reasoning) in reflection.

H_{O5}: There is no statistically significant difference in the proficiency levels in science process skills (planning, performing and reasoning) in refraction with respect to school-type (male only, female only or mixed).

H_{A5}: There is statistically significant difference in the proficiency levels in science process skills) planning, performing and reasoning) in refraction with respect to school-type (male only, female only or mixed).

H_{O6}: There is no statistically significant difference in the proficiency levels in science process skills (planning, performing and reasoning) in reflection with respect to school-type (male only, female only or mixed).

H_{A6}: There is statistically significant difference in the proficiency levels science process skills (planning, performing and reasoning) in reflection with respect to school-type (male only, female only or mixed).

Significance of the Study

Firstly, the tasks 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 would 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.

Delimitations

Though there are other sub-topics in optics, the study focused on only 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.

Again, this study was confined to only three aspects of science process skills, which are planning, performing and reasoning.

Limitations

As much as the researcher tried during the study, he could not control extraneous variables like students learning experience, ability, age, maturation, exposure as well as previous learning, which may have influenced students' science process skills of planning, performing and reasoning of concepts in optics and so may lack internal validity.

Organization of the Thesis

The thesis excluding this chapter has four more chapters, which are sequentially arranged, to give credence to the issues discussed in this chapter and to provide answers to one research question and six hypotheses for the study. Chapter Two is mainly focused on the general review of the relevant literature on the issues relating to the study, namely, assessments of students' science process skills.

Chapter Three focuses on the issues of the research methodology for the study. It describes in detail the type of study and the design, as well as the rationale for the design including the weaknesses and the strengths of the

CHAPTER TWO

REVIEW OF RELATED LITERATURE

Overview

The chapter reviews relevant literature that provides support for the study under the following subheadings: Science Development and Science Assessment, Theoretical framework, Constructivist theory; Assessment, Practical work in Science, Inquiry learning, Science Process Skills and Performance Assessment, among other related topics.

Scientific Development and Science Assessment

Science learning and the development of science process skills are integrated activities. Woolnough and Allsop (1985) argue that the development of science process skills is a valid aim for science laboratory work. Blosser (1988) proposes that there is much theoretical support for the value of laboratory work in helping students to understand science classes. On the basis of these two claims it would seem appropriate to require physics students to acquire competence in some basic science process skills.

Scientific development encompasses process skills, concepts and attitudes. The 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. These process skills are always used in relation to some objects or events; that is, there must be some content in the activity. When pupils or students are observing, exploring and investigating they may gain knowledge about the content and they may also apply existing knowledge to help make sense of what they observe. Concepts develop as students generalize and pick out relationships which link one object or event to another. Thus part of scientific development is a gradual building of a framework of ideas which are used in making sense of further experiences. Attitudes, such as open-mindedness, willingness to take account of evidence, to be persevering and to be critical thinking, are required if students are to use to the full the skills and concepts they have. These process skills, concepts and attitudes can be developed or acquired and used in many areas of the curriculum; observation and the use of evidence can be fostered in diverse projects, practical problem-solving in physics. But if these are the students' only experiences, the development of the skills, concepts and attitudes of science will be very limited. Science - based activities have an important part to play in their development and it becomes greater as the pupils become older and the range of concepts they need to understand their world widens and increases.

The development of these concepts depends upon what is regarded as relevant to be observed and what is investigated depends upon hypotheses based upon previous experiences. The close interaction between process skills, concepts and attitudes means that the use and development of scientific process skills (as quite different from more general skills) are more likely in relation to activities with a science content. The nature of scientific development must inevitably be reflected in the assessment of students.

Theoretical Framework

The constructivist theory advocates the promotion of a learner-centered learning classroom climate (Anderson, 1994). Adopting constructivism means learning is established on the premise that learners are able to construct their

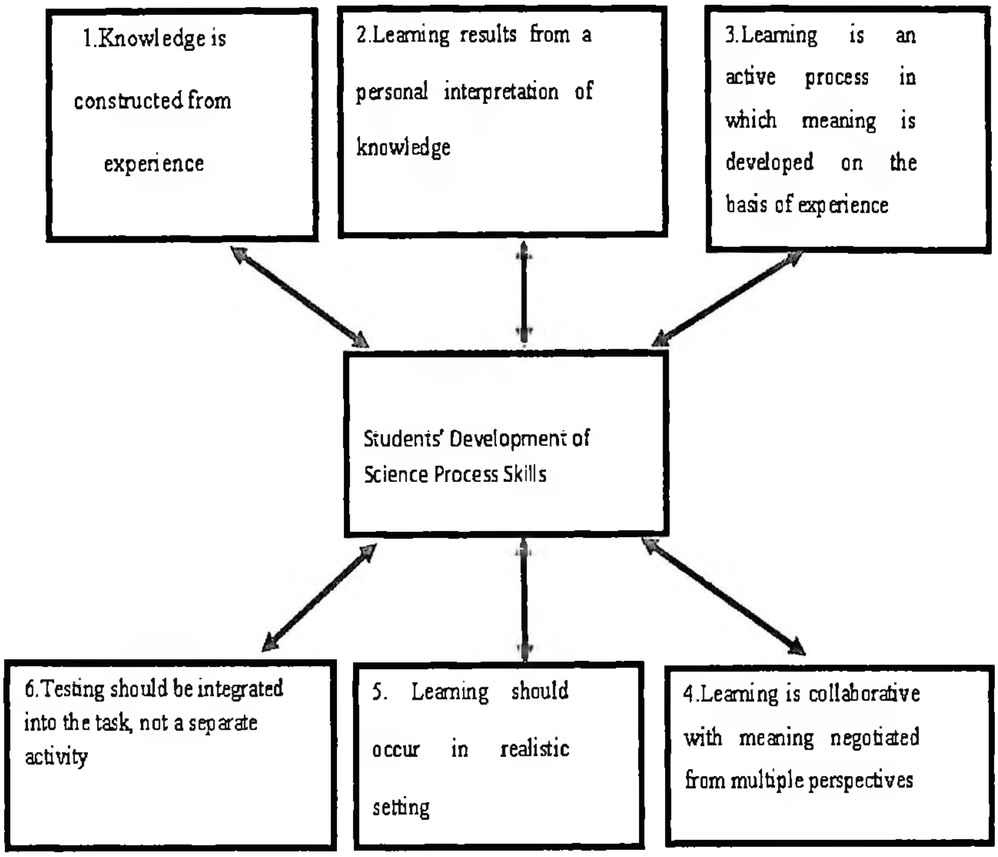

Figure 1: Diagram illustrating the theoretical framework of the study

According to Fosnot and Perry (1996), constructivism is not a theory about teaching but rather a theory about knowledge and learning. The theory defines knowledge as temporary, developmental, and socially and culturally mediated, and therefore subjective. Learning from this angle is understood as a self-regulated process of resolving inner cognitive conflicts that often become apparent through concrete experience, collaborative discourse, and reflection.

Constructivist View of Teaching and Learning

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, Jereme Bruner and Noward Gardner. Constructivism holds that people/students create new knowledge as a result of the interaction of their existing knowledge, beliefs and values with new ideas, problems, visit, knowledge is not universal, objective, but is constructed or co-constructed by learners (Glickman, Gordon & Ross-Gordon, 2004).

The several different models of constructivism can be grouped into two broad categories: The first is cognitive constructivism and the other is social constructivism. Cognitive constructivism is focused on the individual's intellectual development. It holds that learning is stimulated when an individual encounters an idea or experience that contradicts his or her present conception of reality. This anomaly of discrepancy causes cognitive conflict and disequilibrium/imbalance which forces or stimulates the student to develop and assimilate new knowledge as a means of dealing with the anomaly.

Airasian and Walsh (1997, p. 447) discuss what a constructivist approach means for teachers and students:

> i. In a constructivist approach, teachers will have to guide, not tell; to create environments in which students can make their own meanings, not to be handed them by the teacher; to accept diversity in constructions, not search for the one right answer; to modify prior notions or right and wrong, not stick to rigid standards and criteria; to create a safe, free responsive environment that encourages disclosure of students' constructions and not a rather closed or judgemental system.
>
> ii. Students will also have to learn new ways to perform their roles. They will have to learn to think for

> themselves, not wait for the teacher to tell them what to think or do; to proceed with less focus and direction from the teacher, not to wait for explicit teacher directions; to express their own ideas clearly in their own words, not to answer restricted-response questions; to revisit and revise constructions; not to move immediately onto the next concept or idea (p.447).

Glasserfeld (1987) explained that constructivism is a theory that establishes that knowledge is actively built. New knowledge is constructed by the learner out of new experiences. Constructivists hold that learning is an interpretive process as new information is given meaning in terms of the student's prior knowledge. Each learner actively constructs and reconstructs their understanding rather than receiving it from a more authoritative source such as a teacher or textbook (Roth, 1994).

Constructivist learning compared to an objectivist approach in which knowledge is viewed as something which can be imparted. Objectivists like to use the lecture approach because they believe that they can open up the student's head, pour in knowledge, close the student's head and then have the student take a test (Caprico, 1994). This is a dangerous learning approach when viewed in terms of how scientists themselves discover new knowledge.

Constructivist learning has received much support in the literature ranging from philosophical discussions, testimonials by instructors who have seen constructivism work successfully with their students. Experimental studies showed higher student performance in constructivist learning environments (Bodner, 1986; Glasserfeld, 1987; Lawson, 1988; Tobin, 1990;

Leonard, 1991 Caprico, 1994); suggested that having students in collaborative groups is central to a constructivist learning environment because it provides opportunities for students to clarify their understandings.

A Constructivist Approach to Curriculum Development

Working within the general perspective of constructivist epistemology, the central premise is that knowledge, whether public or private, is a human construction. A key feature in this perspective is that human beings construct mental models of their environment and new experience are interpreted and understood in relation to existing mental models or schemes.

Students' conceptions of natural phenomena are also examples of particular types of mental representations; in this case representation of aspects of the natural world which influence the way future interactions with phenomena are constructed. The emphasis in learning is not on the correspondence with external authority but the construction the learner schemes which are coherent and useful to them. This view of knowledge has consequences for our conceptualization of teaching and learning. It will shift the emphasis from the student's correct replication of what the teacher does, to the student's successful organization of his or her own experiences.

It is recognized that individual student's purposes play a role in influencing cognition and behaviour; they act to prioritize attention, to select and order activities in complex situations. In educational setting the importance of the varied purposes of the participant, both teachers and students, is clearly relevant to shaping what is attended to by whom and to what end.

If we recognize that individuals self-construct their own knowledge as a result of interaction between their current conceptions and ongoing experiences, then it is perhaps more helpful to view the curriculum as a series of learning tasks and strategies. Adopting such a view necessarily means seeing the classroom learning environment as complex. The aim in curriculum development is then to create a classroom environment which provides setting for mutual support of knowledge construction. Such an environment includes not only the learning tasks as set, but the learning tasks as interpreted by the learners. It also includes the social organization and modes of interaction between students themselves and between teacher and students. Viewed in this way, curriculum development is inseparable from teacher development. Below are various features which may be seen as characteristics of such a perspective:

i. Learners are not viewed as passive but are seen as purposive and ultimately responsible for their own learning. They bring their prior conceptions to learning situations.

ii. Learning is considered to involve an active process on the part of the learner. It involves the construction of meaning and often takes place through interpersonal negotiation.

iii. Knowledge is not 'out there' but is personally and socially constructed, its status is problematic. It may be evaluated by the individual in terms of the extent to which it 'fits' with their experience and is coherent with other aspects of their knowledge.

iv. Teacher also brings their prior conceptions to learning situation not only in terms of their subject knowledge but also their views of teaching and learning. These can influence their way of interacting in classrooms.

v. Teaching is not the transmission of knowledge but involves the organization of the situations in the classroom and the design of tasks in a way which promotes scientific learning.

vi. The curriculum is not that which is to be learned, but a programme of learning tasks, materials and resources from which students construct their knowledge (Smith & Ragan, 1999. p.15).

Scientific Literacy

Scientific literacy means knowledge and understanding of the scientific concepts and processes required for personal decision-making, participating in civic and cultural affairs, and economic productivity. Science students are being trained by scientific literacy and science process skills through science lessons and classes.

Scientific literacy plays an important role in human daily living. Promotion of scientific literacy has been recognized as a major goal of science education in the world (National Research Council, 1996). Educators agree that scientific literacy should be nurtured as early as possible (Bybee, 1997). Miller, Blessing, and Schwartz (2006) emphasized the importance of civic scientific literacy in a modern society that heavily relies on technology. American National Science Teachers Association (NSTA) recommends that all K-16 teachers embrace scientific inquiry and is committed to assisting educators make it the focus of the science classroom. The use of scientific inquiry will help ensure that students develop a deep understanding of science and scientific enquiry. In view of the stand taken by NSTA (2005), the following declarations are to be followed by all science teachers:

i. view themselves, students, and teaching and learning in a global context;
ii. acknowledge the different value systems and cultures of diverse student populations;
iii. provide and use curriculum materials that includes an international perspective;
iv. learn about effective teaching practices in other countries and cultures;
v. teach about the global impact and importance of scientific issues and concepts; and
vi. engage in international collaborations to improve the quality of science teaching and learning (p. 5).

Although traditional views of scientific disciplines usually include the natural (physical, biological, earth and space) sciences, science can potentially apply to almost any discipline of study including science education. Typical science departments in higher education include biology, chemistry, physics, geology or earth sciences, and frequently mathematics. The contents within all these disciplines are what we call scientific knowledge. It is made up of some progression of observations, facts, hypotheses and theories. Theories were what anchors science, because they affect explanations of natural phenomena.

The most historically recognized component of science has been the accumulated knowledge about the natural world.

Science Process Skills

Educators expect that science students will graduate from their courses and programmes equipped with relevant science process skills as well as problem solving skills. Science teachers are therefore expected to assist develop these skills in their students. Students may follow the laboratory instructions/ procedures outlined in a manual without really understanding the scientific processes. In order to make the laboratory activities more effective, other aspects of science process skills such as identifying problems, developing experimental designs and applying quantitative measures need to be developed by students.

A lot of factors can contribute positively or negatively to enable students perform either creditably or poorly in laboratory skills or science process skills. For example, the under mentioned factors can play a role:

i. Students lack of access to practical activities during teaching and learning.
ii. Practical instructions that are, ambiguous for students during practical sessions (Tamir, 1991).

Science process occurs naturally and spontaneously in our minds. Science process skills are activities that scientists carry out when they study or investigate a problem, an issue or a question. These skills are used to generate content and to form concepts. Science process skills commonly used to describe a set of broadly transferable abilities that are reflective of what scientists do (Ellen, 1995). It is argued that teaching students science facts is not as important as developing their science process skills so that they can acquire new scientific knowledge on their own.

Science studies have shown that instead of using the didactic approach, teaching science through the use of activity-based approaches significantly improve students' achievement in science process skills (Beaumont-Walters & Soyibo, 2001). For effective acquisition of process skills in the laboratory work, initially students need the relevant knowledge that is assumed by the task to be mentally engaged. For example, a more knowledgeable student would be able to explain an observation, which in turn "validates" his knowledge and provides him with a certain amount of intellectual satisfaction. The 'doing' of science has to be matched with 'learning about' science, if students are to appreciate the value of scientific inquiry (Ellen, 1995). Roth and Roychoudhury (1993) found that an experiential approach to science teaching dramatically improved student science process skills. Hence students should be made aware of importance of science process skills. Science process skills are defined as the adaptation of the skills used by scientists for composing knowledge, thinking and making conclusions. Students need hands-on practice to effectively learn and master science process skills. Science activities using process skills allow students to manipulate objects and events, to investigate scientific phenomena, analyze and present their findings. We can use science process skills to find out how to answer questions about how our world works. Science process skill is not just useful in science, but in any situation that requires critical thinking. Science process skills include observing qualities, measuring quantities, sorting/classifying, inferring, predicting, experimenting, and communicating.

forwarded as to how to improve the existing system. One of the more predominant viewpoints is closely aligned with the experimental orientation that was long ago advanced against "cookbook" approaches to teaching subject matter (as has often been the case of science laboratory instructions).

Anderson (1994) indicated that in the future, effective science teachers must assume new class roles. Teachers must become more constructive in nature than instructive. This involves the teacher encouraging students' interaction with their environment ("minds-on and "hands-on"). It is the opinion of several science educators that science education should be practical in nature to a great extent as possible (Ellen, 1995). Engaging in hands-on activities leads to a better understanding of science concepts by providing students with meaningful and concrete experiences.

Many science educators believe that, when properly developed, inquiry skills have the potential to enhance students' constructive learning, conceptual understanding of nature of science (Hofstein & Lunetta, 2004). These laboratory works involve conceiving problems, formulating hypotheses, designing experiments, gathering and analyzing data, and drawing conclusions about scientific problems or natural phenomena, and especially if conducted in the context of, integrated with, the development of scientific concepts and process (Hofstein & Walberg, 1995).

Girls as well as boys actively construct their own reality. External influences play important role as raw material in the process of construction. The point is that girls as well as boys are active agents in their own process of socialization. As a consequence, girls are not individually responsible for their lack of interest in some aspects of science education.

In Ghana, girls and boys have equal access to the same education, specially, science education. Ghana has three types of schools; the boy schools; girl schools and mixed (both boys and girls in one class) schools. The syllabus used for science education from the basic (primary to junior high) schools and senior high school does not discriminate against any sex (boy or girl). Teaching or educational instruction shows no discrimination.

Science process skills can be classified as either basic science process skills or integrated science skills and scientists are only able to use integrated skills effectively once they have mastered the basic skills. Integrated science process skills include skills such as identifying variables, constructing tables of data and graphs, describing relationships between variables, acquiring and processing data, analyzing investigations, constructing hypotheses, operationally defining variables, designing investigation and experimenting .

Science process skills can be decided into two, namely the basic and integrated science process skills (Bredderman, 1983). Basic science process skills include deserving, classifying, measuring, and using numbers, making inferences, predicting, communicating and using the relations of space and time. On the other hand integrated science process skills consist of interpreting data, operational definition, control variables, make hypotheses and experimenting (Curriculum Development Center, 2001). It is important to understand that basic science process skills have to be mastered before developing the integrated science process skills.

Table 1: *Developmental Stages of Process Skills (Meichty1992, p. 441)*

Basic -Developmentally appropriate ages 5 and above	
Observing	Using the sense to collect information
Comparing and Contrasting	Discovering similarities and differences between objects or events.
Classifying	Sorting or ordinary objects or ideas into groups or categories based on their properties.
Measuring	Determining dimensions (length/area), volume mass, weight, or time of objects or events by using instruments that measure these properties.
Communicating	Using pictorial, written or oral language to describe an event, action, or object.
Making models	Making a pictorial, written or physical representation to explain an idea, event or object.
Recording Data	Written down the result of an observation of an object or event using pictures, words or numbers.
Intermediate – Developmentally appropriate for ages 9 -11 and above	
Inferring	Making statements about an observation that provide a reasonable explanation.
Predicting	Guessing what the outcome of an event will be based on observations and, prior knowledge of similar events.
Advanced – Developmentally appropriate for age 12 and above	
Hypothesizing	Stating a problem to be solved as a question
Planning Investigations	Determine a reasonable procedure that could be followed to test an idea or hypothesis-defining and controlling variable.
Interpreting Data	Creating or using tables, graphs, or diagrams to organize and explain information.

Meichty(1992, p. 441)

Scientific Inquiry

Scientific inquiry requires students to use higher order thinking skills as they learn science using a hands-on and minds-on approach. Scientific inquiry shows how scientists come to understand the natural world, and it is the very foundation of how students learn. At an early age, children interact with their environment naturally, ask questions, and seek ways to answer those questions through exploration and curiosity. Understanding science content is very much enhanced when ideas are linked to inquiry experiences.

Scientific inquiry is a very strategic way of understanding science content. Students learn how to ask questions and use evidence to answer them. In the process of learning the strategies of scientific inquiry, students learn to conduct an investigation and collect evidence from a variety of sources, develop an explanation from the data, and communicate and defined their findings or conclusions.

Inquiry is an interactive process that actively and critically engages students in learning meaningful ways. The process of inquiry is characterized by interactive, student-centered activities focused on questioning, exploring, and posing explanations. The major aim of inquiry is to assist students gain a better understanding of the world around them through active involvement and engagement in real-life experiences.

Inquiry is very important in the science classroom because the process of inquiry not only enhances students' understanding of natural phenomena, but also develops students' science process skills. Inquiry is a nonlinear variation of the scientific method. It consists of the same basic components; both the scientific method and the inquiry process require students to conduct research investigations by formulating a question, or develop a hypothesis, conducting an experiment, recording data, analyzing data, and drawing conclusion.

Students in inquiry-based classrooms are provided with hands-on opportunities to engage in science investigations using a more holistic variation of the scientific method. With science teachers playing the role of facilitators of learning, inquiry-based science often consists of group projects, collaboration, student-led investigations, and outdoor explorations, including fieldtrips. Students raise issues in the form of questions, pose hypotheses, research and experiment, analyze their data, and provide very acceptable explanations based on evidence gathered.

Inquiry Learning

Current emphases on interactive, hands-on or inquiry learning are influenced by the constructivist approach which acknowledges the student as actively making his or her own knowledge. Studies of such activities-based science instruction continue to show higher student achievement and engagement (Stohr-Hunt, 1996; Freedman, 1997; NSTA, 2005).

Science education emphasizes the importance of developing students' scientific literacy and thinking skills, as well as improving students' understanding of the nature and process of scientific.

Inquiry is a central component of science learning (Lunetta, 1997). The assumption is that students need opportunities to find answers to real life problems by asking questions, designing and conducting investigations, gathering and analyzing data, interpreting drawing conclusions as well as reporting findings. National Research Council (1996) argues that there is a inquiry process to establish explanations from their observation by integrating what they already know with what they have learned. They learn science concepts, skills, and knowledge to solve problems using practical approaches, which agree with major goals of science education.

Students are really empowered when inquiry is incorporated into the science classrooms. They play active role in their learning rather than the passive role commonly seen in traditional science classrooms. This self-empowerment positively affects students' perceptions about science. Inquiry-based programmes have been found to generally enhance students' performance, specifically performance related to science process skills laboratory skills, graphing skills, and data interpretation. Science education emphasizes the importance of developing students' scientific literacy and thinking skills, improving students' understanding of the nature and process of scientific inquiry has become one of the most important goals of science education.

Ghanaian Senior High School Physics Syllabus: Rationale and Aims

The general science programme offered in Ghanaian Senior High Schools level aims at equipping students with the necessary scientific concepts and skills using the inquiry methods of learning. Below are some sections of the teaching syllabus for elective physics; within the general science programme of SHS(Ministry of Education, 2010).

Rationale for the Teaching of Elective Physics

Physics, as a discipline, deals with the nature of matter and energy, their interactions and measurements. 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 example 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.

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-centered way.

In most Ghanaian classroom, the teaching of physics places much premium on the accumulation of facts rather than on effective methods of inquiry (Bybee, Trawbridge & Powell, 2008). The teaching and learning of physics is facing challenges for both teachers and students due to poor outputs of the WASSCE results according WAEC Chief Examiners reports over a number of years.

General Aims of Elective Physics

The aims of the Senior High School Physics programmes 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, p.ii).

Scope of Content

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 the 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.

Analysis of G.E.S. and WAEC Educational Policy Documents on Physics Practical Work

Physics, as a discipline deals with the nature of matter and energy, their interactions and measurements. The study of physics has had and continues to influence technology the over. At the Senior High School level, the physics programme has one of the chief aims as to, provide through well designed studies of experimental and practical physics, a worthwhile hands on educational experience to become well informed and productive citizen.

The syllabus builds upon the foundation laid in the Junior High school Integrated Science at the Basic Level. The topics have been selected to enable the students acquire the relevant knowledge, skills and attitude needed for tertiary education.

The syllabus (Ministry of Education,2010) 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: Fiber Optics

A total of six periods per week is allocated to the teaching of in each year, with each consisting of forty minutes. The teaching period are divided as follows:

Table 3: *Weekly Theory and Practical Physics Periods*

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

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.

Practical physics according to WAEC will be tested by a practical examination based on the syllabus they provide that was taken from the Ministry of Education Syllabus.

The objective of the practical examination is to test 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 (WAEC physics syllabus).

Assessment

Assessment plays an important role in the teaching and learning process. Classroom as well as laboratory assessment is for decisions concerning students' learning and development. 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, parents can assist and support children with their studies during the school year (Jarvis, 2006).

Assessment may be defined from the instructional standpoint, as a systematic process of determining the extent to which instructional objectives (i.e. intended learning outcomes) are achieved by students (Linn & Gronlund, 1995). Performance has been part of science education for a long time (Kruglak as cited by Ossei-Anto, 1996). 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.

Assessment Process

The assessment process consists of both measurement procedures (i.e. tests) and non-measurement procedures (e.g., informal observation) 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.

It is important to recognize that skills have to be used in relation to some context. The challenge here in assessing science performance process skills will be influenced by type of "setting" or context of the task, as does in the assessment of the application of concepts, since a school or laboratory setting may signal that a particular kind of thinking is required whilst an everyday domestic setting would not provide this prompt.

Some Modes of Assessment

Educational assessment can be seen as an approach by teachers to obtain the level of students' knowledge, skills and attitudes on various issues of educational interest. Educational assessment goes beyond the techniques teachers and examining bodies use when grading students. It is also a means to assist students learn and teachers improve their instruction. Assessment activities are to generate information that serve many functions of significance to both the learner and the teacher. Teachers may adopt the information for summative or formative purposes.

According to Rowntree (1977) there are various modes of assessments including the following: formative versus summative, formative versus informal, coursework versus examination, continuous versus terminal, process versus product, convergent versus divergent and internal versus external. Science graduates at both the senior high and tertiary levels should show documentary evidence of a comprehensive picture of their abilities and experiences, assessment in science should be broadened to include more practical assessment. The issue of the assessment of practical skills and the outcomes of practical work are of vital importance. Currently, efforts are being made for effective methods of enhancing assessment using performance –based procedures.

Formative Assessment

Formative assessment has been defined as the process of appraising, judging or evaluating student's work or performance using this to shape and improve students' competence. Formative assessment is seen as a crucial development. A distinct characteristic of formative assessment is that the assessment information is used, by the teacher and students to modify their work in order to make it more effective (Black, 1995).

Formative assessment encompasses all activities undertaken by teachers which provide information to be used as feedback to modify the teaching and learning activities in which they are engaged. It emphasizes the learning process and is usually conducted on a daily basis (Black, 1993).

Formative assessment is believed to be productive in optimizing teaching practice in ways that support students learning. Evidence can be found in literature that formative assessment practices can result in improved student learning (Bell & Cowie, 2001). Black and Wiliam (1998) reported consistent learning gains for students when assessment practices were well designed and used in a formative approach.

The major principles of formative assessment include identifying students' weaknesses and strengthens, enhancing students motivation and providing feedback to inform teaching and learning (Moeed, 2010).

Summative Assessment

Most of the debates about higher education in the United States have focused on the curriculum, or what is taught. Only in recent decades is the focused changed to the subject of scholarly inquiry, analysis and evaluation (Cowie & Bell, 1999). This may be a result of latest development in which assessment has played a fundamental role in education policy in the United States. Large scale, summative assessments are viewed as powerful levers for influencing what happens in schools and classrooms, and as such assessment studies are done, routinely to gauge the strengths and weaknesses of students. In the United States results from large-scale summative assessment, along with other measures of achievement are used to determine whether students can advance to the next grade, and to judge the quality of schools and the educators who work in them.

In recent years, educators, business leaders, and policy makers in the United States have questioned whether the current design of assessment systems focuses too much on measuring students' ability to recall discrete facts using multiple choice tests.

Performance Assessment

Performance assessment is sometimes referred to as "alternative" assessment or "authentic" assessment, in as much as "authentic" assessment focuses on the practical application of the tasks in real-life setting. The value of instruction can be markedly increased when accompanied by an evaluation of learning that occurs.

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.

Performance assessment is viewed as a process that is critical in the hope of creating a more rounded science students who may be more inspired to continue his/her education in science beyond the constraints of the high school experience.

In education one must plan his/her students' performance assessment task with vigor. Why is this preplanning so necessary? First you must assess what it is that should be included as a performance assessment task. Second, you must ascertain if this particular skill/ability will fit within the constraints of the performance assessment paradigm, within the context of your particular classroom? Besides the time variable that will be entailed in performance assessment tasks, a scoring rubric must be created to suit the tasks.

In carrying out performance assessment tasks in science, it is always good to make the tasks quite specific to the curriculum of the studies for that particular subject. The tasks should comply with clear instructions and diagrams of what particular performance assessment entails.

Performance assessment is that which require students to demonstrate that they have mastered specific skills and competencies by performing tasks. Advocates of performance assessment calls for assessment of the following type: designing and carrying out experiments; working with other students to accomplish tasks, demonstrating proficiency in using a piece of equipment or a technique and analyzing of data (Moore, 1998). In education one must plan his/her student's performance assessment task with rigour. Why is this preplanning so necessary? Why is this preplanning so necessary? First one must assess what it is that should be included as a performance assessment task. Second, one must ascertain if this particular skills/ability will fit within the constraints of the performance assessment paradigm, within the context of your particular classroom/laboratory. Based on the time variables that will be entailed in performance assessment tasks, a scoring rubric must be created to match the in carrying out performance assessment tasks in science. It is always good to make the tasks quite specific to the curriculum of the studies for that particular subject. The tasks should be complied with clear instructions and diagrams of what that particular performance assessment entails.

For performance assessment procedure to by 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). Constructed- related validity can make inferences about the degree to which a respondent possesses some trait or theoretical construct from test results. It seeks to ask the question: What do these test scores really mean? Comparatively, content- related validity refers to the sample of questions in a given test/ questionnaire which represent the important content, skills or behaviours of the domain of interest. It is a well-accepted that school assessment serves two major purposes: summative and formative.

Performance assessment is said by its advocators to be more in line with instruction than multiple-choice tests. With an emphasis on a closer similarity between observed performance and the actual criterion situation, it can also in a positive way guide instruction and student learning and promote desirable student attitudes. Again, it is viewed as having better possibilities to measure complex skills and communication, which are considered important competencies needed in today's society.

When performance assessment is described in terms of its characteristics, that is, by means of typical properties of such assessments, the descriptions mostly involve cognitive process required by the students, but also the inclusion of contextualized tasks and judgmental marking in the assessment. When concrete examples are given, they are mostly in very close resemblance with criterion situations, demonstrating higher order thinking and communication.

To assess students on scientific reasoning and understanding rather than simply measuring discrete knowledge, critical assessment methods were developed, with a focus on performance-based assessment. A proponent for this type of assessment (Wiggin, 1998) argues that a performance-based assessment methodology provides students with meaningful paths to demonstrate their knowledge. Again, the technique also improves students' skills by bringing into play complex functions of cognitive processing that require a higher order thinking skills.

Performance-based assessment provides teachers with information about how a child understands and applies knowledge. Also, teachers can integrate performance-based assessments into the instructional process to provide additional learning experiences for students.

Performance-based assessment, with its ability to provide students with rich, contextualized, and engaging tasks, can also assist students to choose or design tasks a questions that are meaningful and interesting to them, can make adjustments based on student experiences and skills, and can test student individually, "to ensure that the student is fully examined" (Wiggin, 1998, p. 708).

Advantages and Limitations of Performance Assessment

Advantages

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).

Limitations

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).

Checklists

The checklist uses the yes or no idea. It is basically a method of recording whether a characteristic is present or absent or whether an action was or was not taken. Performance assessment checklists are to ascertain whether a skill is demonstrated or not. Again checklists are useful in assessing those performance skills that can be divided into a series of specific actions. In addition to its use in assessing process, the checklist can also be used to assess products; here the form usually contains a list of characteristics that the finished product should possess.

Planning Skills

Planning is the process of deciding what to do and how to do it. Planning can be seen in all disciplines of learning. It is therefore both an art as well as a science. It needs judgment, sensitivity and creativity. Plan deals with the in-between issues and hence require preparation to stay at it. Good planning requires a methodical step-step process to the optimal right solutions. An effective planning will require that one will correctly define the problem as well as ask the right critical questions.

This category is concerned with some of the skills that students have to use in finding things out for themselves or test out their ideas. The ability to plan investigations, in part or whole, involves recognizing the various factors which may affect the result, identifying which of these have to be changed, which content, what measurements or observations have to be made to detect the result, what sequence or order of procedures will enable these things to be put into practice and how the results will be used to solve the initial problem.

The following observations were made by Ossei-Anto (1996) in a similar study:

i. less than 40% of the sample produced a plan that was detailed enough to solve the given problems.
ii. on safety precautions, over 80% of sample did not include any in their plan.

Performing Skills

Performing skills can only be acquired in the physics class and programme when the students are taken through series of hands-on and minds-on activities for them to become familiar with whatever instruments, tools or equipment without really engaging students in the practical work on performance, no process skills cannot be developed. An important part of science at any age (from basic up to tertiary) is using process skills and concepts in solving problems and carrying out investigations. A useful assessment must be able to say something about performance in such situations. The assessment must be able to describe the various different kinds of performance which made up the whole. One way of doing this is to observe the various process skills, attitudes and concepts which science students deploy.

Under performing tasks, Ossei-Anto (1996) observed that many students did not relate theory to practice in their presentation.

Reasoning Skills

It is important to note that science education reform documents have emphasized assisting students develop scientific reasoning skills as a major goal for science education. Science educators believe that reasoning skills play an important role in students' ability to develop scientific understanding and hence conduct scientific investigations (Lawson, 1992).

Reasoning is defined as specific type of thinking that involves drawing inferences from initial premises and is closely related to judgements, decision-making and problem solving. In accessing reasoning skills students can be given diagrams to take measurements using various instruments as well as estimate quantities. Students are sometimes confronted with pre-determined amounts of materials and asked to estimate the quantity provided. Students are required to read scales, use appropriate units and to use measuring instruments and other laboratory situations. Using the concepts in the scientific investigations, various calculations and conclusions are drawn.

Again, under reasoning tasks, on sources of error, less than 50% of the sample was successful (Ossei-Anto, 1996).

Marking and Categorizing Answers for Performance Assessment

The marking schemes indicate how numerical scores are assigned to answers. Clearly marks are only given to responses which answer the question posed, however correct they may be in other respects. Assigning scores to answers is, however, only one way in which assessments are marked. More useful to teachers and others concerned with the school curriculum are the results of describing all the kinds of answers that students give, whether scoring or not. Knowledge of incorrect, incomplete and unexpected answers can be of rather more help in reviewing students learning experiences than just knowing how many were correct. For a number of questions, much more detailed marking schemes are used, which enable a report to be made on students misunderstanding and misconceptions.

Assessment and Context

The role of context in the learning process as it has been influenced by the learning psychology of Ausubel and promoted by constructivism has important implications for assessment. The essence of constructivist philosophy is clearly expressed in the fact that knowledge is generated a person's constructive activity (Glassersfeld, 1990). Hence, learning is a sense-making activity by the learner whereby he/she tries to accommodate new information to existing mental structures. New information is always connected to similar information where conceptual overlap or context is the most dominant factor. Hence by this reasoning, one arrives at the importance of context to the learning process, since information cannot exist in isolation in the long-term memory, and again in the reasoning process there are constant attempts to make links or connections among concepts. One may ask, what does the word context mean in the science educational setting? According to Baker, O'Neil, and Linn (1993, p. 1215):

> The term context has different and somewhat conflicting meanings. Some proponents use context to denote domain specificity. Performance in this context would presumably show deep expertise. On the other hand, context has been used to signal tasks with authenticity for the learner. The adjective authentic is used to denote tasks that contain true-to-life problems or that involve skills in applied context.

The importance of context for assessment can be viewed from two angles. If knowledge is tested in a decontextualized fashion, it is not necessarily clear what is been tested. Testing for a particular piece of knowledge or skill in a decontextualized manner will not tell the assessor to what degree this knowledge or skill has been integrated within the long-term memory structures. The same assessment task performed some time later might produce a different outcome for the same student. The value of knowledge gained through cramming to produce a correct answer to a test question is questionable since that knowledge will be forgotten sooner than later (Johnson, 2012). By taking into account various context in assessment, one gets a clearer picture of how the knowledge has been integrated and whether this knowledge can be used productively by the learner or student.

Another way in which context is applied in assessment is in students' demonstration of their ability to use or apply knowledge. In the application of knowledge, the presence of context is natural and important. Cognitive research shows that the ability to apply knowledge is fairly domain specific, meaning that the cognitive structures relating to performance of a particular task in a given setting do not generalize to the performance of a similar task in another setting.

The selection of a context for a task is important since the assessment may not be relevant to a wide range of ability. Literature contains a number of recommendations as to the desired characteristics of assessment. One important theme is that contextualized assessment should reflect "real-life" (i.e., outside of the laboratory or the classroom) tasks and which require students to use higher order thinking skills (Crotty, 1994; Leon & Elias, 1998).

Assessment in the Practical Context and the Nature of Performance Assessment

Assessment of performance skills in the practical context was proposed by assessment experts as an answer to the decontextualized nature of conventional testing and as a way of testing thinking skills of higher order than those tested by conventional methods. The nature of performance assessment requires that the student demonstrates science process skills and knowledge in practical work, that is, hands-on and minds-on in a real-life setting. Typical science performance assessment provides students with laboratory equipment, poses a problem, and allows students to use these resources to generate a solution (Ruiz-Primo & Shavelson, 1996).

It is important to note that performance assessment differs a little from well-designed science laboratory experiments and laboratory examinations that have been used for decades by competent science teachers from senior high school level to tertiary level by lecturers. The tasks of performance assessment are meant to present the student with an unfamiliar situation so that he/she may attempt to generate the answer. It is not primarily a factual or procedural recall.

The basis for performance assessment, according to Khattri, Reeve, and Kane (1998), is that the current push toward using performances is partly due to the reaction on the part of educators against pressures for accountability based on multiple-choice, non-referenced testing, the development in the cognitive sciences of a constructivist model of learning. The constructivist reorientation of science education has brought about a greater emphasis on inquiry-based learning. From the perspective that student's learning is largely self-constructed, and experiential, it is a logical and straight forward step to promote activity-based assessment.

Improving the Validity and Reliability of Performance - Based Tests

When students carry out performance assessment tasks, they apply their background knowledge in interpreting the tasks and in constructing meaning of the tasks and their demands (Linn & Gronlund, 2000).

Norm-Referenced and Criterion - Referenced Assessment

Assessment score needs to be referenced to something outside the assessment to be interpreted. Two types of score-referencing procedures are important currently, they are called norm-referencing, and the other criterion-referencing. Norm-referenced interpretations describe assessed performance in terms of a student's position in reference to that of the group that has been administered the assessment. The referenced group is called the norm group. Criterion-referenced interpretations describe assessed performance in terms of the kinds of tasks a person with a given score can do.

It is important to note that both kinds of interpretations are important to understand how well a student is learning. Students performing poorly relative to their peers may require special attention. On the other hand, it is what students are able to do that is most important and critical to our decision. For instructional decisions, a teacher must know such particulars as the kinds of skills a student has already learned, the degree to which skills can be performed.

An assessment can be described in terms of its objectivity; the degrees to which every observer of a student's performance will give almost the same report or result. Objectivity and subjectivity refer to the scoring aspect of assessment rather than the type of items. In fact objectivity is a matter of degree. Standardization can improve the objectivity of assessments as well as the validity of interpreting the observation or procedures; administrative procedures, equipment and materials, and score rubrics have been fixed so that, as much as possible, the same scientific procedure is followed during each period of occurrence at different times and places. The main reason for standardizing an assessment procedure is to permit fair comparisons of different students on different occasions (Doran, 1980).

Task Construction

Ideas for constructing or selecting practical, effective and meaningful performance assessment tasks were adopted from Linn and Gronlund (2000). They indicated that development of high level performance assessment tasks require attention to task constructs and ways in which the tasks are scored. The following strategies were suggested:

i. Identify learning outcomes for the topic from curriculum documents (e.g. syllabus), then identify outcomes that require complex skills and content and which cannot be adequately assessed by other assessment modes;

ii. Constructed tasks that focus on the selected outcomes;

iii. Avoid inclusion of irrelevant skills that may interfere with interpretation and implementation of the task;

iv. Include inform in the tasks that will indicate students the knowledge and skills that are necessary to perform the task;

v. Provide scaffolding for the students to help them understand the task and its expectations. Students should be familiar with required in the assignment of grades, but they do not provide student with specific feedback about strengths and weakness of their performance as provided by analytic rubrics (Miller, Linn & Gronlund, 2009).

Science Laboratory Work

Laboratory instruction had long had a significant role in science education and literature abounds of skills developed by students from engaging science laboratory activities including; planning, performing as well as measuring skills (Freedman, 1997; Hodson, 1990; Hofstein & Lunetta, 1982; Tobin, 1990). Development of laboratory skills and science process skills required in the process and procedures of science and understanding of basic knowledge in science, as products, are considered to be major goals of science at all levels. The laboratory activity has been viewed as an important role in order to attain these goals. Science process skills learning has been considered to become an important component of science curricula at all levels by many educators (Okey, 1972).

On the other hand, Friedler and Tamir (1986) pointed out that by and large, the outcomes of studying science using laboratory-oriented activity fell short of expectations. Woolnough and Allsop (1985) argue that one reason for the failure is the attempt to use the practical work it is an ill-suited way, such as teaching theoretical concepts instead of focusing on the real aims of practical experience. It is important to note that laboratory skills and science process skills cannot be developed just by transmitting the body of knowledge without "minds-on" and "hands-on" experience through laboratory-oriented inquiry activities.

Despite the usefulness of laboratory work, the students do not focus on their purposes. That is, students try to see or determine only the expected results from the activities, but do not invest much effort in relating other learning experiences to laboratory work and also laboratory instruction should give students wider scope of learning experiences than just verifying textbook claims. Currently, the main thrust of science classrooms has been on mastering and doing science as it is practiced in the real laboratory situations by scientist (Ellen, 1995). Today's scientific instruction emphasizes on problem-solving, inquiry-based laboratory activities and rejects science as a body of facts that must be memorized.

Laboratory work allows students to plan and to get involved in investigations or to take part in activities that assist them to improve the manipulative skills. Developing practical skills and scientific learning methods, students acquire high level of motivation and teachers have the opportunity to evaluate the knowledge and skills of the students.

The purpose of laboratory work in science education includes assisting students learn science through the acquisition of conceptual and theoretical knowledge, and assisting them learn about science by developing an understanding of the nature and method of science (Hofstein & Lunetta, 1982). Laboratory work also stimulates the development of analytical and critical thinking skills and manipulative skills that create interest in science. Some science educators agree that laboratory work is indispensable to the understanding of science (Ampiah, 2004; Ossei-Anto, 1996). It is vital to note that two major goals of laboratory work are to link theory and practice and to stimulate students' interest and excitement (Ottander & Grelsson, 2006).

Authentic and Student-Centered Learning

Funding agencies and organizations in the U.S.A promoting college science education have strongly recommended that institutions of higher education provide greater opportunities for authentic, interdisciplinary, and student-centered learning (National Research Council, 1999). Many have suggested that teachers' views of science teaching play important roles in influencing their actual practices (Blake, 2002; Lederman, 1992; Pajares, 1992; Sweeney, Bula & Cornett, 2001).

Four Broad Epistemological Themes Underpinning Science Practical Work

Four broad concepts on how students are likely to perceive and pursue inquiry in the science classroom/lab and on what students might learn about nature of science (NOS) through such inquiry. Below are the four broad conceptions (Tsai, 2007, p. 222):

i. Scientific knowledge is constructed: Students need to understand that scientific knowledge is constructed by people, not simply discovered out in the world. In fact, science may be best characterized as the effort to explain observations of the natural world. What that means is that there is always a relationship between theory and observation. There are consequences to the belief that scientific knowledge is constructed. One is that creativity plays an important role in the development of scientific knowledge, as human creativity is the source of theoretical ideas. Again scientific knowledge is not accepted because it is "true", but because people are persuaded of its value, i.e., its adequacy as an explanation, or its utility, or some other standard.

ii. Diversity of Scientific Methods for Students to properly understand science and effectively conduct inquiry. Students should know that scientific methods are diverse. Part of the diversity in methods stems from the differences among scientific disciplines, as they explore different kinds of phenomena. The main scientific objective is that claims about the natural world have to fit with and make sense of observations of that world. Epistemologically, the goal is to assist students develop standards for evaluating the fit between observations, methods of obtaining them, and the knowledge claims advanced through them.

iii. A third epistemological goal is that students should understand that there are different forms of scientific knowledge, varying in their explanatory or predictive power and in their relation to the observation world-example: Within a sophisticated scientific epistemology, these entities vary in scope and purpose. For instance, laws are typically understood as generalized descriptions of some phenomenon with high predictive value but little explanatory power. Theories, in contrast, are conceptual frameworks that provide relatively high degrees of explanatory power and varying degrees of predictive value. Besides theories, laws, and hypotheses, models are important forms of scientific knowledge.

iv. Students need to understand that scientific knowledge is tentative (Lederman, 2002); in other words scientific knowledge is not absolutely true. The importance of the notion that scientific knowledge varies in its degree of certainty for reforms is important. The removal of absolute certainty takes away authority with respect to knowledge from teachers towards students.

Practical Work in Science Education

The laboratory has long been given a central and important role in science education. It has been used to involve students with concrete experiences with concepts and objects. Since the end of the 19th century, when schools began to teach science systematically, the laboratory became an important feature of science education. After the 1st World War, with the rapid increase of scientific knowledge the laboratory was used as a means for conformation and illustration of information learned previously in a lecture or from a textbook.

Laboratory activities are defined as learning experiences, in which students interact with materials to observe phenomena. The experiences may have different levels of structure specified by the teacher or laboratory handbook, and they may include phases of planning and design, analysis and interpretation and application as well as the central performance phase. Laboratory activities usually are performance by students individually or in small group.

In the United State of America in the 1960s, a new curricula was introduced which resulted in several new intentions for the role of laboratory work. In the new curricula which stress the process of science and emphasize the development of higher cognitive skills, the laboratory acquired a central role, not just as a place for demonstration and confirmation, but as the core of the science learning process (Shulman & Tamir, 1973). Science educators have expressed the view that the uniqueness of the laboratory lies principally in providing students with opportunities to engage in processes of investigation and inquiry. Laboratory also provides students the ability or skills to appreciate the methods or systems of science education, includes: promoting problem-solving, analytical and generalization abilities with some understanding of the nature of science.

All aspects of science involve a practical component. The importance of task-based activities in practical science in developing scientific process skills is well documented by Woolnough (1991), Millar (1991) and Gott and Mushiter (1991). Assessing reports of practical work may only involve measuring the quality of the end-product of the practical work, not the work itself.

Practical component of a science course like elective physics is just as important as theoretical competencies. Student graduating from SHS and entering the university to say pursue electrical engineering will be expected to enter the research area or industry and will be expected to have acquired a wide range of practical skills.

Again, employers may need to know how good students' practical skills are and not just how good their reports are. Hence, it is useful to reverse part of our overall assessment for practical skills themselves, and not just the final written products of practical work. Practical work is learning-by-doing.

Increasing the importance of practical work by including assessment to it assists students approach such work more seriously and critically.

There are some setbacks to assessing science practical work. It is quite difficult to assess practical work critically. It is usually much easier to assess the end-product of practical work rather than the process and skills involved in their own right. Quite often it can be difficult to agree on assessment criteria for practical skills. Again, some students may be nervous when they realize they are being observed during the performance.

Strategic Questions and Hints for Improving Assessment in Science Practical Work

It is critical to address a number of issues about the nature and context of practical work, the answers will assist clarify how best to go about assessing such work. According to (Shulman & Tamir, 1973), for students to understand the scientific enterprise, scientists and how they work in the laboratory provided some questions as well as hints are stated below:

i. What exactly are the practical skills we wish to assess? These may include a vast range of science process skills- planning, investigating, performing, reasoning, etc. It is vital that students know the relative importance of such skills.

ii. Why do we need to measure practical skills? Students after graduation will be judged by the skills they have acquired by entering the next level or when they enter employment. It is often said by employers that students are very knowledgeable, but not necessarily competent in practical tasks.

iii. Where is the best place to try to measure these skills? Practical skills can be measured in places like laboratories or workshops. Other skills, students may need to be in working in real-life situations.

iv. When is the best time to measure practical skills? When practical skills are critical to the complete understanding and proficiency of the course. It is best to start measuring them very early on in a course, so that difficulties can be identified and remedied.

v. Who is in the best position to measure practical skills? For many practical skills assessment, they only valid way of measuring them involved someone doing detailed observations while student demonstrate the skills. This can be very time-consuming, since it limited the number of students you can assess within a given period.

vi. Is it necessary to establish minimum acceptable standard? In fact it cannot be anything goes; minimum level of proficiency should be arrived at (Shulman & Tamir, 1973, p. 1119).

Goals for Laboratory Activities

Hofstein and Lunnetta (1982) suggested an organization of the goals for science teaching that have been used over the year to justify the importance of laboratory teaching. These goals are grouped in cognitive, practical, and affective domains as shown in Table 4.

Table 4: *Goals of Laboratory Activities*

Domain	**Goals**
Cognitive	i. Promote intellectual development ii. Enhance the learning of scientific concepts iii. Develop problem-solving skills iv. Develop creative thinking v. Increase understanding of science and scientific method.
Practical	i. Develop skills in performance science investigations ii. Develop skills in analyzing investigative data iii. Develop skills in communication iv. Develop skills in working with others v. Enhance attitudes toward science vi. Promote positive perceptions of one's ability to understand and to affect one's environment.

Purpose and History of Practical Work

Practical work in school is carried out in different ways. In terms of the practical component of school science practical work, is according to Millar (2004) any science teaching and learning activity in which students work alone or in groups, observe and /or manipulate the objects or materials they are studying. It is argued that practical work in school science may be used by teachers as illustrations of phenomena, to give students a type of feel of the phenomenon, or as exercise or steps to follow to develop a particular skill. Woolnough and Allsop (1985) classified school practical work as exercises, investigations and experiences. Exercises are for skills development, including correct use of laboratory equipment while investigations involve problem solving in open-ended tasks. A broader definition of practical activities in school science is learning experiences in which students interact with material or with secondary sources of data to observe and understand the natural world. If the purpose of practical work is to gain an understanding of scientific investigation, then according to Ellen (1995), learning about science has to be linked with doing science.

Practical work was first introduced in schools in the nineteenth century in Britain according to Afkin and Black (as cited by Sani, 2014). The purpose was more than just doing experiments to confirm a theory that was already known. Instead, it was to find out something that had not been known in previous generation of novel ideas. Earlier in the Twentieth Century, a "cookbook" approach (also referred to as recipe practical work) with an emphasis on practical skills, following instructions and confirming well - established results was common. Practical work was about "learning by doing" and would confirm the theory presented in the textbooks (Ellen, 1995).

In the United Kingdom, Wellington (as cited by Sani, 2014), describes three phases of practical work in the latter half of the 20th Century, the discovery approach, the process approach, and investigation. The first, the discovery approach was described by Hodson (1990) that it promoted observations as theory-free, and required a leap from experimental to theory through inductive process.

The criticism of the second phase, the process approach, was because it implied that the process of science (observing, predicting, inferring, designing, etc.) could be learnt out of context. It was underpinned by the belief that skills could be transferred from one context to another, and that the less able learners could learn the skills even if they could not understand the context. The belief was that any student could learn science however, Hodson (as cited by Sani, 2014) disagreed, and asserted that the transfer of practical skills to another context is not achieved by most students. Investigation, the third phase, was introduced in England and Wales in 1989. Millar (2004) said engagement in practical activities is essential for developing understanding in concepts formation. Millar thinks the role of practical work in the teaching and learning of science content is to help the student to make links between two "domains" of knowledge as shown in Figure 1.

Figure 2: Practical work: Linking two domains of knowledge (Millar, 2004, p. 8).

Millar indicates that the teacher acts as a facilitator for students to make links between the two domains. Abrahams and Saglam (2010) suggested that teachers' three broad aims in terms of practical work can be categorized into three domains: procedural, conceptual, and affective. They observed that teachers want:

i. to encourage accurate observation and accurate/careful recording.

ii. to promote simple, common-sense, scientific methods of though.

iii. to develop manipulative skills

iv. to prepare pupils for assessed practical work.

v. to arouse and maintain interest in the subject.

vi. to make biological, chemical and physical phenomena more real through actual experiences (Abraham & Saglam 2010, p. 726).

Science Laboratory Practical Work

A great many different objectives work, formulated from very general to very specific and from student-centered to teacher-centered exist. Flansburg (1972), in a study found out that, while new curricula emphasize the process of science, stressing higher cognitive skills, such as concepts attainment, problem solving and critical thinking, students completing science courses involving laboratory work can do little if any, better on examination than students completing equivalent courses not involving laboratory work.

Kirschner and Meester (1988) reveal the following criticism (both from students and staff) of science practical work provides a poor return of knowledge in proportion to the amount of time and effort invested by staff and students. This does not mean that the skills and knowledge gained from the laboratory work is small in comparison to the time and effort spent. This criticism is compounded by the tendency towards the emphasis of higher order cognitive skills such as concepts attainment. Whether one is an adherent of the discovery method (Brunner) or there expository method (Ausubel) of concept attainment, one prominent common features to both approaches is the necessity of practice or repeated exposure to instances of the concept. An experiment may provide a demonstration of a concept, but it is only one, single demonstration.

Most often, the work done in a laboratory simply verifies something already known to the students. This tends to reduce student motivation to investigate, providing disservice to both student and the discipline in question (Physics, Chemistry or Biology). According to Tamir (1977), schools both at the secondary and tertiary levels, spend too much time having students perform trivial experiments. It is quite easy to perform practical work which does not involve any thinking at all. Sometimes exercises are given to students which overwhelm them, because they are beyond them; as if to punish them to think. Sometimes supervision of laboratory works is often inadequate; assignments are not marked and returned within a period of time so as to have an effect on learning. Often constructive feedback is lacking and practical work is often seen as isolated exercises, having no bear on or little relationship with earlier or future work.

Laboratory work is part of the requirement of the study of general science at the senior high level in Ghana. Traditionally, students are given a detailed manual for each laboratory assignment to be carried out. Specific details on how data is observed, analyzed and interpreted are then explained to the students. In short, students just follow instructions and finally they are required to submit their reports; normally individually, though most often due to lack of equipment and large class size they work in groups. Often in such a situation students do not show high level of interest and understanding. They view laboratory work as burdensome as they cannot see the real link between the work done at the laboratory with actual everyday problems (Rivarola & Garcca, 2000).

Science laboratory work or science practical has a huge potential. Among the attributes that can be instilled into students through properly conducted work are:

i. ability to work in groups.
ii. ability to choose and use appropriate instruments and tools.
iii. ability to design experiments.
iv. ability to observe, analyze and interprete data.
v. ability to have deeper understanding of the real world through experiments.
vi. awareness on the need for lifelong learning (NRC, 1996, p. 23).

Laboratory activities are important for students to build their experiences and science concepts, gain problem-solving skills, work in co-operation and develop science process skills. Laboratory activities in science education allow students to provide meaningful learning, use science process skills and also recognize the process how to build the knowledge they learn in science lessons.

Laboratories allow students to explain principles, processes, and experiments with samples by searching and inquiring (Tamir, 1977). In laboratory method, learning takes places through sense on the other hand by applying scientific method in laboratories; students gain scientific knowledge and develop problem-solving skills. Students learn how to design and pursue an experiment and reach the results by themselves. Students use science process skills when they do work in the laboratory. Laboratory method in science education is important to gain and develop science process skills (Hodson, 1990; Hoffstein & Lunetta, 1982; Tamir, 1977).

Criticisms against Practical Work

There appears to be an overall agreement that laboratory work at present provides a poor return of knowledge in proportion to the amount of time and effort invested by staff and students. This does not mean that laboratory work is not important, but instead that the skills and knowledge gained from this work is small in comparison to the time and effort spent to gain this knowledge. Most often, the work done in a laboratory simply verifies something already known to the student. Students spend too much time performing trivial experiments (Tamir, 1976). Non-trivial exercises are often beyond the comprehension of students and often the period to complete them is too short.

Laboratory work consists of activities that require materials, tools and equipment that cost money as well as taking up students' time and energy. Thus, it has to be optimally used so that it can become a learning experience which brings a lot of benefits to both students and teachers.

Physics Laboratory Work

Laboratory work has always been an integral component of the physics curriculum at all levels. Research in physics education in the last few decades have helped in the evolution of instructional objects in physics laboratories and there has been a shift towards creating new learning environments to promote meaningful engagement in the learning of physics (Ossei-Anto, 1996). Laboratories in such models are mostly based on "discovery" or "guided" learning.

For a long time, physics laboratory instruction has all along consisted primarily of performing pre-set repetitive experiments; students are to go through a prescribed series of steps to normally verify certain laws, concepts or theories learnt in theory. Such as routine exercise neither promotes scientific investigative skills nor an in-depth understanding of what was observed and experimented with i.e. development of science process skills. The result therefore is that most students tend to view physics as merely an abstract collection of laws, mathematical equations and textbook problems rather than a way of understanding and modeling physical phenomena; hence physics is considered very difficult by the average science student. This situation continues to prevail despite some innovations introduced at various levels by individuals, researchers or institutions. These, however have not led to any major reforms in teaching-learning in the conventional physics laboratories at the senior high school level in Ghana. In fact, activity without understanding seems to be a regular feature of classroom life for physics students in Ghanaian schools and hence the WAEC result depicts it clearly with most students obtaining poor (WAEC, 2014).

Science learning and the development of science process skills are integrated activities Woolnough and Allsop (1985) argue that the development of science process skills is a valid aim for science laboratory work. Blosser (1988) proposes that there is much theoretical support for the value of laboratory work in helping students to understand science teaching.

Science Education and Gender

Some scholars have argued that sex differences in science-related occupation and educational choices cannot be accounted for by differences in school to the senior high school levels. The initiative has produced a number of prominent females in science and technology who are at present playing major roles nationally and internationally. Currently, a second look should be given to that strategy and see whether it can be overhauled and tried again

Some amount of work had been conducted in the area of gender and science education as well as achievement (Greenfield, 1996). The impressions and findings of these researchers are mixed; no one particular gender dominates (i.e. neither, male or female). According to Ssempala (2005), there are more similarities than differences between performances of females and males on practical laboratory tasks despite well-established sex-related differences in areas of interest, such as science-relevant experience and confidence. Gender differences in achievement have been observed in teacher grades and in standardized test for many years (Connelly, 2008).

According the Shaw and Nagashima (2009), girls outperformed boys on performance assessment in an inquiry-based classroom. Ossei-Anto (1996) observed that males outperformed females on planning tasks whilst females outperformed males on performing and reasoning tasks. A similar study conducted by (Johnson, 2001) revealed that females outperformed males on planning, performing and reasoning skills. Goldin, Katz and Kaziemko (2006) in their study, found out that female high school students outperform male students on most subjects especially in science and mathematics.

The trends in International Mathematics and Science study documents international trends related to science achievement among 46 countries. Among U.S fourth graders in 2007, males outperformed females in science however, the differences were not significant (Mullis, Montin & Foy, 2008).

Possible explanations why females perform poorly than males in science have been identified to include the following: differences in teacher support, parental support, motivation, enrolment patterns and hands-on experience. Gender, especially in relating to the girl-child, has been a big issue in Ghana for more than two decades leading to the establishment of STME for girls in the middle 1990s. The argument has been that, girls, if given equal opportunities like boys would perform equally or even better. According to Greenfield (1997) girls and boys often experience qualitatively different educational situations in areas especially science and mathematics. Greenfield indicated that these differences can have impacts that go beyond college and into their professional years. It is evident in science classrooms and laboratories as teachers involve boys more than girls in science practical work. Often, boys are called upon to answer questions, and receive more detailed process feedback on their efforts. It may be preferable to present girls' with science materials and problem solving activities in ways that encourage different approaches to doing science (Howes, 2002).

School Types

In Ghana there are single-sex schools (male only and female only) and mixed (co-educational) schools. According to Salomone (2006) single-sex education has a long history and traditional in the United States of American. According to Salomone (2006) the first single-sex schools in United State of America were for male only students. Single-sex schools for girls arose later, and it grew out of the exclusionary admissions policies of all education have been the preferred method of instructions. On the other hand mixed or co-education has been dominant in the public domain since the beginning of education for the masses (Salomone, 2006).

The belief held in the 1800s that single-sex education in the United States of America originated in society that valued education only for males. He indicated that the all-girls' schools that were eventually created were a reaction to the exclusion of females from the halls of learning. Others feel argument for single-sex education can be made on the basis that male dominance in the classroom does not lead to equal educational opportunities. There have been studies that demonstrate the success of females in single-sex classes. Some of these studies attribute this success to the absence of a male population.

According to Salomone (2006) co-education had success in the early stages in rural areas where it was found to be a simple and effective way to educate children in sparsely populated areas. The merits and drawbacks of single-sex education have been hot topics in education for a long time. There are many studies that demonstrate the positive effects of single-sex education. One the other hand there a number of studies that try to show that single-sex education isn't as beneficial some might think.

Single-sex schools benefit both males and females, because they provide a stronger academic climate and reduce distractions.

There are other advantages as well; that is the type of school will have an impact on the course that boys choose as well. It is believed that in the single-sex environment boys will be more like to pursue their actual interest, rather than being pressured by stereotypes to pursue "traditional" boys course.

Some researchers argue that boys are a cause of anxiety in a co-educational classroom.

Even though many studies have shown single-sex education to be beneficial in many ways, there are other researchers that would say the research is skewed and that single-sex education is not as beneficial as co-educational learning environments. On the whole, a number of studies have shown the benefits of single-sex education over co-education, and there are a number of studies that indicate the ineffectiveness aspect of single-sex education. Currently, there are no establish conclusion as to which is more valuable. At the moment the educational community needs more careful research upon which to give critical recommendations.

The achievement levels of students attending single-sex schools compared to that of students attending co-educational schools is often an issue normally debated. Dhindsa & Chung (2003) conducted a study that demonstrated that single-sex schools are better at achieving higher academic levels.

It is important to note that not all researchers support the conclusion that single-sex schools are responsible higher academic levels. Some researchers argue that there are factors other than of the sex of the students, which have an important impact on the successes of single-sex schools. One such hypothesis is that single-sex schools perform better because most are private and can select their students from the best.

Why Optics (Reflection and Refraction) was Chosen for the Study

Optics was selected because it has several applications. We use the ordinary mirror to look at our faces and when polishing up, again in supermarkets as security checks. Drivers use the driving mirror for direction. Refraction has a lot of applications that include: Real depth and apparent when it comes to swimming in a pool or using lenses (converging or diverging) to look at objects and toys of all kinds are made from lenses and mirrors. Therefore, it is easy to build on that knowledge by introducing reflection and refraction at the lower level (SHS 1).

Some Everyday uses of Refraction of Light

It must be noted that there is a convex lens in the eye(s) of every human being. When we see an object, the light from the object is being refracted by the lens of the eye, forms an image on the retina. We are able to see the object when a real and inverted image of that object is formed on the retina. Hence, refraction of light enables us to see an object (Avison, 1989).

Again there are many people who have defects in their eyes. Among them some cannot see a distant object, others cannot see near object. These defects can be remedied using spectacles made by lens of particular power; here the optometrist plays a major role in the correction.

Another application is the concept of real and apparent depth in a swimming pool; where the actual depth of the water is far deeper than what is normally perceived. Hence swimmers are warned to be careful when diving and swimming.

Refraction provides science educators as well as scientists with data about the composition and structure of bodies in space. In the area of technology application refracted light is central to the operation of fiber optic cables using laser sources. By constructing a cable made of differentiated layers of glass, each with its own refractive index, it is possible to send a pulse of light down a cable, for a consider distance without losing its intensity in the process. The refractive gradient between layers of glass inside the cable keeps light of a particular wave length travelling forward along the cable rather than being absorbed or redirected in a way that interrupt the signal.

Other applications include; a lens using refraction to form an image of object for many different purposes, such as in magnification. A prism uses refraction to form a spectrum of colours from an incident beam of light. Not forgetting the important role refraction plays in the formation of mirages and other optical illusions.

Refraction of light is made use of in aquarium that houses coloured fish. The light from the fish coming through water at first falls on the glass of the aquarium. After the refraction of light through the glass, the sight reaches our eyes and we enjoy their interesting movements.

By using the property of refraction of light we can take photographs with a camera, we can see very small objects magnifying it by a microscope and see far/distant objects by telescope.

Some Everyday Uses of Reflection of Light

Reflection of visible light allows us to see objects that do not produce their own light. Reflection of visible light is often used for aesthetic purposes, example in auditorium during musical concerts. Reflection of light, especially, total internal reflection is used in inkless finger print readers.

Again optical fibers have revolutionized the communication industry the world over. The fiber optic cable – a thin flexible glass fiber with a coating, carries light through a distance of several kilometres, with little loss of its energy and hence its intensity, due to total internal reflection. This is made possible by keeping the outer layer known as cladding less dense relative to the inner dense care-the condition for total internal reflection. Light enters almost parallel to the fiber, the angle of incidence is high and it easily exceeds to critical angle that allows total internal reflection to occur.

The flexibility of the fiber, light mass, low cost and the ability to send light signals through them with very little loss of light (intensity/energy), make them indispensible in modern communication networks.

Summary of Related Literature

The summary of related literature had been argued in the following sections namely: knowledge, construction; learning, environment, purposes and motivation, inquiry, teaching, practical work, performance assessment and testing and gender.

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.

Science is usually viewed stereotypically as a domain that males prefer and are more competent at, compared to females. It is true that females compared to males have some perspectives that are different in science and technology and females should be encouraged to offer careers in these areas. Some amount of work had been conducted in the area of gender and science education as well as achievement. The findings of these researchers are mixed, no one particular gender dominates (i.e. neither male nor female).

CHAPTER THREE

RESEARCH METHODS

Overview

This chapter deals with the research design, method, instruments and procedures of the study. It includes sampling procedures, the methods of data collection for both the pilot testing of the instruments and the main study. It also provides the means by which data collected was analyzed in terms of mean scores, standard deviation, percentages, correlation, ANOVA and MANOVA.

Research Design

The aim of this study was to assess the proficiency levels of SHS Form 2 science students (i.e., those who offer physics, chemistry, biology and mathematics as electives) in optics (reflection and refraction). Specifically, the study assessed the proficiency levels of students' process skills in planning, performing and reasoning of the concepts of reflection and refraction in optics. Based on this aim, the study adopted a survey design to assess the proficiency levels of students' process skills in reflection and refraction in optics. This design was the most appropriate because it allowed the researcher to gather data on a one-shot basis to represent the SHS Form 2 science students in a target population of science students in the Cape Coast Metropolis on their proficiency levels in optics.

Although, this design enabled the researcher to assess the proficiency levels of students' process skills in optics, it should be noted that the design did not allow for changes that may occur after the collection of the data.

did only one task either Tasks A or Tasks B but not both. Table 5 presents the age distribution of students for Task A and Task B

Table 5: *Distribution of Ages of sample for Task A and Task B*

	Task A		**Task B**	
Age	**N**	**%**	**N**	**%**
15	2	1.4	1	0.9
16	52	36.9	33	28.9
17	65	46.1	70	61.4
18	20	14.2	6	5.3
19	1	0.7	4	3.5
20	1	0.7		
Total	**141**	**100**	**114**	**100**

From Table 5, majority of the sample were within the ages of 16 years and 17 years, that is 83% and 90.3% for Task A and Task B respectively. The extreme ends are 15years (1.4% and 0.9% for Task A and Task B respectively) and 20 years (0.7%) for Task A. The two tasks A and tasks B were in the areas of refraction and reflection respectively.

Data Collection Instruments

The main research instruments for data collection were Tasks A on refraction and Tasks B on reflection. The two instruments were adapted from Ossei-Anto (1996). They were performance tasks with an additional opinionnaire for respondents to give their opinions on each of the performance assessments tasks they undertook. Tasks A on refraction and Tasks B on reflection was adapted from the format used by Ossei-Anto (1996) and was used but scenarios and diagrams used for the current tasks were developed by the researcher.

Tasks A on Refraction consisted of the following subheadings:

i. Planning task (Task A_1)
ii. Performing task (Task A_2)
iii. Reasoning task (Task A_3)

Task B on Reflection also consisted of the following subheadings:

i. Planning task (Task B_1)
ii. Performing task (Task B_2)
iii. Reasoning task (Task B_3)

The tasks were designed in such a way that each task in, say refraction (Task A_1, Task A_2 and Task A_3) are independent of the others; that is one does not need any data from the other(s) to enable one to work on the other activity/activities (see Appendices B and C for items on Tasks A and Tasks B respectively).

Validity

Face and content validity of the instrument were looked at by science educators from the Department of Science and Mathematics Education, during a seminar presentation as a requirement for improvement of the instruments. This was to enable the instrument to measure what it is supposed to measure.

Pilot Testing

Pilot testing of the instruments was done from the 20th November, 2013 and ended on the 28th November, 2013 using three schools in the Eastern Region of Ghana whose students offer physics, chemistry, biology and mathematics as electives. These schools and sample selected have the same characteristics as the sample used in the main study. Two streams of science class were selected from each of the three schools and out of each stream 40 students were randomly sampled to take part in the pilot testing (i.e., 20 students for Task A and 20 for Task B). However, 66 students took part in the testing since some opted out. In all, 33 students took part in Tasks A and 33 students took part in Tasks B.

Reliability

The reliability coefficient of all the tasks (planning Tasks A and B; performing Tasks A and B; reasoning Tasks A and B) were calculated using Cronbach Alpha correlation coefficient. Table 6 presents the reliability coefficients for the tasks (see Appendix G).

Table 6: *Tasks A and Tasks B reliability coefficients for the pilot testing*

Tasks	**Cronbach Alpha**
Task A_1	0.789
Task B_1	0.735
Task A_2	0.907
Task B_2	0.849
Task A_3	0.846
Task B_3	0.820

As shown in Table 6, Task A_1 and task B_1 had reliability coefficients of 0.789 and 0.735, quite close. Task A_2 and Task B_2 had 0.907 and 0.849 respectively, also quite close in values. Again Task A_3 and Task B_3 had 0.846 and 0.820 respectively, which were quite close / similar in value (see Appendix G) for SPSS output of the reliability coefficients for the tasks). In

Subtasks that Constitute levels of Proficiency for Tasks A and Tasks B (Table 8)

a. Planning skills for Tasks A and Tasks B
    i. Two appropriate answers out of six is low proficiency.
    ii. Three appropriate answers out of six is moderately high.
    iii. Four appropriate answers out of six is high.
    iv. Five or more appropriate answers out of six is very high.
b. Performing skills for the Tasks A and Tasks B
    i. Three appropriate answers out of seven is low proficiency.
    ii. Four appropriate answers out of seven is moderately high proficiency.
    iii. Five appropriate answers out of seven is high proficiency.
    iv. Six or more appropriate answers out of seven is very high proficiency.
c. Reasoning Skills for Tasks A and Tasks B
    i. Three appropriate answers out of nine is low proficiency.
    ii. Five appropriate answers out of nine is moderately high proficiency.
    iii. Seven appropriate answers out of nine is high proficiency.
    iv. Eight or more appropriate answers out of nine is very high.

Table 8: *Categorization of Proficiency Levels- Science Process Skills in Refraction and Reflection*

Range of Values	Proficiency
0 – 0.40	Low
0.41 – 0.60	Moderately High
0.61 – 0.80	High
0.81 –1.00	Very high

Key to No Credit and Full Credit of Scoring for the Analysis:

I. No credit can mean the following:
   i. No response
   ii. Inappropriate response (wrong answer)
   iii. No response and inappropriate response
   iv. The above = No credit = 0

II. Appropriate response (correct answer) = Full credit = 1.

Data Collection Procedure

Permission was sought from the headmasters/headmistresses and the physics teachers of the seven schools to allow me use the classes concerned for the study. Permission was granted and the students sampled after rapport was established were informed of the intended study.

The two groups of students took only one of the two tasks (either Task A or Task B). Again, each student in a particular group was expected to do all the three tasks provided in Task A or Task B. For instance, each student took only one of the three tasks at a time; for refraction in planning; performing and reasoning. Each task with the two parallel areas of refraction and reflection using a three way MANOVA using the mean scores for boys only, girls only and mixed school-type students in planning, performing and reasoning in reflection. The researcher scored the tasks and put in measures using scoring rubrics to make sure that scoring was very objective.

CHAPTER FOUR

RESULTS AND DISCUSSION

Overview

In this chapter, the results of the study are presented and discussed in relation to two research questions and the six hypotheses that were tested. All hypotheses were tested at 0.05 level of significance.

Proficiency Levels of Physics Students in Science Process Skills of Planning, Performing and Reasoning in Optics (Refraction and Reflection)

Research question one sought to find out the performance levels of physics students in science process skills of planning, performing and reasoning in refraction and reflection in optics. This was done using Tasks A and Tasks B. Frequencies and percentages were used to measure the proficiency levels students exhibited.

Planning Skills

The results and proportions of students' with full credit and no credit in the skill of planning are presented in Table 9. As shown in Table 9, for the general strategy, 82.3% of.the students showed adequate proficiency in Tasks A_1 and 77.3% of the students showed adequate proficiency in Tasks B_1. On detailed plan, only 22.7% of the students showed adequate performance in Tasks A_1 and 28.1% showed adequate performance in Tasks B_1. As shown in the results, students showed, except for general strategy, low performance levels in both planning skills for tasks in refraction and reflection. The trend shown can be attributed to lack of consistent, effective laboratory practical work. This probably led to poor general performance of students in planning skills. Two of the inappropriate and two appropriate answers given by students for Task A_1 and Task B_1 respectively are presented.

Table 9: *Proportion of Students with full credit and no credit in planning skills for Task A_1 and Task B_1*

Skill	**Task A_1 (Refraction) N=141**		**Task B_1 (Reflection) N=114**	
	Full Credit	**No Credit**	**Full Credit**	**No Credit**
General strategy	116 (82.3)	25 (17.7)	88 (77.2)	26 (22.8)
Sequential plan	69 (48.9)	72 (51.1)	59 (51.8)	55(48.2)
Detailed plan	32 (22.7)	109 (77.3)	32 (28.1)	82 (71.9)
Workable plan	22 (15.6)	119 (84.4)	8 (7.0)	106 (93.0)
Appropriate Diagram	52 (36.9)	89 (63.1)	19 (16.7)	95 (83.3)
Safety Procedures	39 (27.7)	102 (72.3)	45 (39.5)	69 (60.5)

Note: The figures in brackets represent percentage.

Research question two sought to find students appropriate and inappropriate responses for (a) planning, (b) performing and (c) reasoning in refraction and reflection tasks. Below are some of the examples students normal appropriate and inappropriate responses:

Two Students Inappropriate Answers for Task A_1 (Planning Skills)

Answer One

"As my role to ensure the lenses do not get mixed up, I will ensure that specific or unique labels are placed on each patient's lens to ensure that they are easy to identify. For example: Ama – focal length 15 cm will have an identifiable notation. Efua – focal length 20 cm will also something different. Kofi – focal length 25 cm will also have a different label." (Appendix B)

Answer Two

1. "First of all the focal length of the schools must be indicated on a sheet of paper before you proceed.
2. I make sure all the apparatus I will need are available before I start work.
3. A concave mirror is placed on the desk.
4. An object is placed at a relatively far distance from the concave mirror.
5. The focal lengths of the various schools are determined by converging at the incident parallel narrow beam of light from the distant object to the focal points."

Two Students Appropriate Answers of Task A_1 (Planning Skills)

Answer One

"Since the ray of light from an object converges at a point known as the focal length is equal to the distance between the convex lens and the focal point,

1. I would get a screen.
2. Place the convex lens before it.
3. I would try to capture a distance object on the screen by moving the convex lens in its lens holder.
4. I will try and capture a sharp clear image. In doing so I will stop moving the lens holder and measure from the lens to the screen and this will determine the focal length of each of the lenses.
5. By doing so, I will be able to start out the lenses for the patients."

Answer Two

As stated above, the rays from the sun as a distance object passing through the lens must meet at the focal points of the lenses of Ama, Efua and Kofi, To ensure this,

a. A screen must be placed in front of the lens and when a sharp image is obtained, the focal length is being measured between the lens and the sharp image.

   The procedure is applied for all three convex lenses and the focal length is recorded and grouped.

b. For lens A, the focal length is 15cm which is supposed to be for Ama.

c. For lens B, the focal length turns to be 20cm which is for Efua.

d. The last lens that is lens C has the focal length of 25cm which is for Kofi.

e. To obtain the focal length of a lens, it must be adjusted to form real, inverted and diminished image on a screen. The image must be also sharp to ensure the correct focal length. (Appendix B)

Two Students Inappropriate Answers for Task B_1 (Planning Skills)

Answer One

1. "For each school, the eyes or vision will be checked using a laser, so as to get an accurate.
2. After this, the accurate information is provided and therefore one can check the focal lengths of various concave mirrors.
3. An object is placed in front of a concave mirror to determine the focal length as the principal focus may be known.
4. The concave mirror is turned at various angles so as to know the optical power.
5. When the optical power is determined, the object distance is

determined, the object distance is measured and the image distance as well.

6. The focal length is then calculated using the formula:

$$\frac{1}{f}=\frac{1}{u}+\frac{1}{v}$$

7. This procedure is repeated over and over again for accurate measurements."

Answer Two

1. "Take your concave mirror.
2. Measure the length in cm from the mirror to a point and that would be the focal point and the distance f would be the focal length.
3. Incident light rays on the mirror and make sure their reflected ray converge at the focal point."

Two Students Appropriate answers for Task B_1 (Planning skills)

Answer One

"Considering a lot of mirrors, there would be 3 big plastic boxes which are open. Each labeled A, B, and C respectively.

1. I would then use a light producing medium to reflect on 3 different mirrors.
2. Assuming the mirrors have different focal lengths I would try and observe the one with the shortest distance at which the light rays converge after reflection from the mirror and place it in A.
3. The mirror with the furthest converging point is assumed to be having a focal length of 30cm thus put in Box C.
4. The mirror having a not-so-long-not-so short distance put in

Box B.

5. This process is continued as they are compared with each other for sorting to be achieved.
6. All this procedure is done in front of a fixed white medium, be it cloth or paper.
7. The mirrors are place in a holder at a fixed place.
8. The light procedure is also supposed to be stationary."

Answer Two

1. "To send the mirrors without mixing them up according to the orders placed by schools A, B and C of focal lengths, 10cm, 20cm and 30cm respectively; at a point where the image will be formed at infinity.
2. An object is place in front of the concave mirrors.
3. The point at which the object is placed for the imaged to be formed at infinity is noted or recorded.
4. The distance between the object and the concave mirror is recorded. That is the focal point/length.
5. This procedure is repeated on and on.
6. The mirrors with the same focal length are grouped at one side.
7. Hence the mirrors with the focal length as 10cm are distributed to school A.
8. Mirrors of focal length of 20 cm are given to school B.
9. Mirrors of focal length 30 cm are given to school C."

Performing Skills

Task A_2 and Task B_2 were both to assess performing skills, but Tasks B_2 was in the area of reflection of light using two plane mirrors inclined at varied angles while Task A_2 was in the area of refraction of light through a rectangular glass block. Task A_2 and Task B_2 were quite different compared to the planning tasks (i.e., Task A_1 and Task B_1 that were quite similar and parallel in concept).

Task B_2 involve counting or identifying the number of images produced as well as the observation and recording of the pattern for each angle of inclination to two mirrors, whereas Task A_2 involve refraction of light through a rectangular glass block.

The result of the student proficiency in performing skills in refraction is presented in Table 10.

Table 10: *Proportion of Full Credit and No Credit of Students for Task A_2 (Refraction)*

Component Assessed	**No Credit**	**Full Credit**
1. Accurate value of i_A	55(39.0)	86(61.0)
2. Accurate value of r_A	99(70.2)	42(29.8)
3. Accurate measurements from drawing sheet	64(45.4)	77(54.6)
4. Accurate value of i_B	122(86.5)	19(13.5)
5. Accurate value of r_B	72(51.1)	69(48.9)
6. At least two correct values of the sine function	122(86.5)	19(13.5)
7. Accurate value of f	125(88.0)	16(12.0)

Note: The figure in brackets represent percentage.

As shown in Table 10, most of the students could not measure the angles of the images produced by the rectangular glass block.

The results of the students' proficiency in performing skills in reflection are presented in Table 11.

Table 11: *Proportion of Full Credit and No Credit of Students for Task B2 (Reflection)*

Component Assessed	**No Credit**	**Full Credit**
1. Accurate value of images, n, seen with mirrors at 120°	22(21.1)	90(78.9)
2. Accurate value of images, n, seen with mirrors at 90°	24(21.0)	90(78.9)
3. Accurate value of images, n, seen with mirrors at 72°	30(26.3)	84(73.7)
4. Accurate value of images, n, seen with mirrors at 60°	43(37.7)	71(62.3)
5. Accurate appearance of images seen	34(29.8)	80(70.2)
6. Accurate pattern/trend of number of images	67(58.8)	47(41.2)
7. Accurate appropriate safety procedure stated.	86(75.4)	28(24.6)

Note: Figures in brackets are percentages.

As shown in Table 11, majority of the students could handle the images produced or formed by the two inclined plane mirrors, however, quite a number of the students could not handle the trend or pattern formed by the images in the inclined plane mirrors.

Two of the inappropriate and two appropriate answers given by students for Task A_2 and Task B_2 respectively are presented.

Two Students Inappropriate Answers of Task B_2 (Performing Skills)

Answer One

Angle between two inclined standing plane mirrors	Total number of image seen in both plane mirrors
120°	3

90°	4
72°	5
60°	6

Description (I)

1. Images are in each mirror but there is only one clear and sharp image with the other image becoming blur or faint.
2. Images are real.

Description (II)

1. With the 120° and the 60°, the number of images produced is same.
2. With the 72°, the number of images produced is twice that of the 90°.
3. Finally, with the 90°, only 4 images were produced.
4. Images are real.
5. Images are not very clear.

Answer Two

Angle between two inclined standing plane mirrors	Total number of image seen in both plane mirrors.
120°	10
90°	6
72°	5
60°	4

Description (I)

1. When the mirrors were inclined at an angle of 120°, 10 images were formed. The left mirror produced 5 images and the right mirror also produced 5 images.

2. When the mirrors were inclined at an angle of 90°, three images were formed on each mirror giving a total of 6 images.
3. When the mirrors were inclined at angle of 72, five images were formed.
4. When the mirrors were inclined at angle of 60°, four images were formed.

Description (II)

As the angle reduced, the number of images formed also reduced accordingly, were produced by both mirrors.

Two Students Appropriate Answers of Task B_2 (Performing skills)

Angle between two inclined standing plane mirrors	Total number of image seen in both plane mirrors.
120°	2
90°	3
72°	4
60°	5

Description (I)

1. When the mirrors are inclined at 120°, the images are of the same size as the object. The images are at the same position/distance as the object.
2. I observed at almost all the angles at which the plane mirrors inclined, all the images formed were the same size as the object. All the images distances from the images from the object were the same no matter the images formed.

Description (II)

1. The pattern I observed was that the images were arranged in a clockwise trend with same image distance from the object in question.
2. When the mirrors were inclined at 120° I observed that the images were adjacent to the object and so were the others.

Answer Two

Angle between two inclined standing plane mirrors	Total number of image seen in both plane mirrors.
120°	2
90°	3
72°	4
60°	5

Description (I)

1. The images appear to be the same distance away from the surface of the mirror as the object is from the surface of the mirror.
2. The image is the same size as the object.
3. The image is not real as it is formed behind the mirror.
4. The image can be formed many times depending on the angle at which the mirror surfaces are inclined while the objects number remains the same.

Description (II)

The number of images formed follows a particular trend, obtained from the formula:

$$n = \frac{360}{\theta} \quad 1$$

Where n = number of images formed

θ = angle at which the two mirrors are inclined.

Two Students Inappropriate Data Tables for Task A_2 (Performing skills)

Answer One

Angle of Incidence i/°	Angle of refraction r/°	Sin i	Sin r
i_A= 60°	r_A = 60.2	0.866	0.8677
i_A= 40°	r_B = 0.642	0.6428	0.6420

Answer Two

Angle of Incidence i/°	Angle of refraction r/°	Sin i	Sin r
i_A= 60°	10.2	0.87	0.18
i_A= 40°	10.1	0.64	0.18

Two Students Appropriate Data Tables for Task A_2 (Performing skills)

Answer One

Angle of Incidence i/°	Angle of refraction r/°	Sini	Sinr
i_A= 31.0	r_A = 21.0	0.515	0.358
I_B = 51.0	r_B = 30.0	0.766	0.500

Answer Two

Angle of Incidence i/°	Angle of refraction r/°	Sini	Sinr
i_A= 31.0	r_A = 20.0	0.500	0.342
I_B = 50.0	r_B = 31.0	0.766	0.515

Reasoning Skills

Task A_3 and Task B_3 were parallel and require the students to measure distances and record data in a table form; compute the reciprocals of *v* and *f*, and provide appropriate sources of errors. The result of the student proficiency in the skill of reasoning is presented in Table 12.

Table 12 - *Proportion of Full Credit and No Credit of Students for Task A_3 (Refraction)*

Component Assessed	**No Credit**	**Full Credit**
1. One or two accurate values of u.	28(19.9)	113(80.1)
2. Addition one/two accurate value of u.	30(21.3)	111(78.7)
3. One or two accurate values of v.	18(12.8)	123(87.2)
4. Additional one/two accurate value of v.	36(25.5)	105(74.5)
5. At least two values of $\frac{1}{u}$	41(29.1)	100(70.9)
6. At least two accurate values of $\frac{1}{v}$	45(32)	96(68)
7. At least two accurate $\frac{1}{f}$ values.	58(41.1)	83(58.9)
8. At least two accurate f values.	59(41.1)	82(58.2)
9. Accurate appropriate sources of error.	114(80.9)	27(19.1)

As shown in Table 12, almost 60% and above showed high levels of proficiency in measuring distances and recording data in table form, and computing of the reciprocals of *v* and *f*. However, 80.9% students could not provide appropriate sources of error.

The credit distributions for the nine items on these tasks are found in Table 13.

Table 13: *Proportion of Full Credit and No Credit of Students with Task B_3 (Reflection)*

Component Assessed	**No Credit**	**Full Credit**
1. One or two accurate values of u.	13(11.4)	101(88.6)
2. Addition one/two accurate value of u.	14(12.3)	100(87.7)
3. One or two accurate values of v.	14(12.3)	100(87.7)
4. Additional one/two accurate value of v.	15(13.2)	100(87.7)
5. At least two values of $\frac{1}{u}$	10(8.8)	104(91.2)
6. At least two accurate values of $\frac{1}{v}$	84(73.7)	30(26.3)
7. At least two accurate $\frac{1}{f}$.values	89(78.1)	25(21.9)
8. At least two accurate f values.	92(80.7)	22(19.3)
9. Accurate appropriate sources of error.	76(66.7)	38(33.3)

Note: The figure outside the bracket represent frequency and the figure in the bracket represent percentage.

As shown in Table 13, over 80% of the students exhibited satisfactory levels of proficiency in measuring distances and recording data in table form. However, over 78% students could not compute the values of the reciprocals of *v* and *f*, and also provide appropriate sources of error.

Two of the inappropriate and two appropriate answers given by students for Task A_3 and Task B_3 respectively are presented.

Two Students Inappropriate Data Tables for Task A_3 (Reasoning skills)

Answer One

Object Distance u/cm	Image Distance v/cm	$\frac{1}{u}$	$\frac{1}{v}$	$\frac{1}{f}$	F

1. 4.4	4.4	0.23	0.23	0.46	2.17
2. 3.4	8.8	0.29	0.11	0.40	2.50
3. 6.0	4.2	0.16	0.24	0.40	1.56

Answer Two

Object Distance u/cm	Image Distance v/cm	$\frac{1}{u}$	$\frac{1}{v}$	$\frac{1}{f}$	$^{f}/_{cm}$
1. 4.5	5	0.2	0.2	0.1	10
2. 3.0	8.8	0.33	0.114	0.084	12.1
3. 6	4.2	0.1667	0.238	0.098	10.2

Two Students Appropriate Data Tables for Task A_3 (Reasoning skills)

Answer One

Object Distance u/cm	Image Distance v/cm	$\frac{1}{u}$	$\frac{1}{v}$	$\frac{1}{f}$	$^{f}/_{cm}$
1. 5.0	5.0	0.20	0.20	0.40	2.50
2. 3.4	8.9	0.29	0.11	0.41	2.46
3. 6.0	4.2	0.17	0.24	0.41	2.47

Answer Two

Object Distance u/cm	Image Distance v/cm	$\frac{1}{u}$	$\frac{1}{v}$	$\frac{1}{f}$	$^{f}/_{cm}$
1. 4.9	4.9	0.20	0.20	0.40	2.5
2. 3.4	8.8	0.29	0.11	0.40	2.5
3. 6.0	4.2	0.17	0.24	0.41	2.4

Answer Two

Object Distance u/cm	Image Distance v/cm	$\frac{1}{u}$	$\frac{1}{v}$	$\frac{1}{f}$	f/cm
1. 9.90	9.90	0.10	0.10	0.20	5.00
2. 14.80	7.30	0.14	0.14	0.21	4.94
3. 2.50	-5.0	0.40	-0.20	0.20	5.00

According Galili and Hazan, (2000) students find the topic geometric optics to be obscure and difficult. Studies show students have learning difficulties with lenses in geometric optics (Galili, 1996; Galili, Bendall, & Goldberg, 1993; Goldberg & MacDermott, 1987). On the other hand reflection tasks had higher proficiency levels because of the everyday use in the households. The finding that students were more proficient in the reflection tasks than refraction tasks is consistent with earlier findings.

Proficiency Levels of Physics Students Science Process Skills in Refraction

Hypothesis one tested whether there was statistically significant difference in the proficiency levels in physics students' science process skills (planning, performing and reasoning) in refraction. A one-way analysis of variance (ANOVA) was used to compare the mean scores of students in planning, performing and reasoning for refraction tasks.

Table 14 shows the descriptive statistics and proficiency levels for the variable of tasks.

Table 14: *Means, Standard Deviation and Proficiency levels for Refraction Tasks (Planning, Performing and Reasoning skills)*

Dependent Variable	Mean	S. D	Proficiency level
Planning skills	0.39	1.29	Low
Performing skills	0.34	0.28	Low
Reasoning skills	0.64	0.28	High

As shown in Table 14 the mean scores for planning, performing and reasoning skills for refraction are 0.39, 0.34 and 0.64 respectively, hence students reasoning skills was high compared to performing and planning skills which were both low.

A one-way between groups analysis of variance was conducted to assess the proficiency levels of elective physics students in process skills of planning, performing and reasoning. There was statistically significant difference in mean score between the groups. The effect size, calculated using eta squared gave a value of 0.18.

Table 15: *Analysis of Variance (ANOVA) Results on Refraction with respect to Planning, Performing and Reasoning Skills(N= 141)*

Source	Df	Sum of Square	Mean Square	F	P	Eta Squared
Between Groups	2	7.547	3.774			
Within Groups	420	33.732		47.0	0.001	0.18
Total	422	41.280				

Significant p<.05

Post-hoc comparisons using the Tukey HSD test indicated that the mean score for planning (M= 0.39, S.D = 0.29) was significantly different from reasoning (M = 0.64, S.D = 0.28), with reasoning being more proficient, see Table 13. Again there was statistically significant difference between performing tasks (M = 0.34, S.D = 28) and reasoning tasks (M = 0.64, S.D = 0.28), with reasoning task more proficient than performing. There was no statistically significant difference between planning task (M = 0.39, S.D = 0.29) and performing task (M = 0.34, S.D = 0.28), see Table 14.

Table 16 is the post-hoc for the refraction tests showing a means for groups in homogeneous subsets. Comparing the above results with that of Ossei-Anto (1996) he had performing tasks as the highest proficiency whilst planning and reasoning tasks had lower comparable proficiencies. This may be attributed to more hands-on learning of physics as required in the U.S.A (Tamir, 1991).

Table 16: *Post-Hoc comparing means among groups in homogeneous subsets for Refraction Tasks*

					95% Confidence Interval	
(I) refraction	(J) Refraction	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
Planning	Performing	.05066	.03375	.292	-.0287	.0300
Planning	Reasoning	-.25461*	.03375	.000	-.3340	-.1752
Performing	Planning	-.05066	.03375	.292	-.1300	-.0287
	Reasoning	-.30527*	.03375	.000	-3947	-.2259
Reasoning	Planning	.25461*	.03375	.000	.1752	.3340
	Performing	.30527*	.03375	.000	.2259	.3847

The mean difference is significant at the 0.05 level

Proficiency Levels of Physics Students' Science Process Skills in Reflection

Hypothesis two tested whether there was statistically significance difference in the proficiency levels for physics students' science process skills (planning, performing and reasoning) in reflection. A one-way analysis of variance (ANOVA) was used to compare the mean scores of planning, performing and reasoning for reflection tasks.

On Table 17 is displayed the descriptive statistics for variable for tasks.

Table 17: *Results for Reflection Tasks (Planning, Performing and Reasoning skills)*

Dependent Variable	Mean	S. D	Proficiency level
Planning skills	0.37	0.27	Low
Performing skills	0.61	0.28	High
Reasoning skills	0.59	0.24	High

As shown in Table 17 the mean scores for planning and reasoning were: 0.61 and 0.59, respectively. Hence performing and reasoning are moderately proficient and planning quite low in proficiency. Students were more proficient in performing than in planning. There was also a statistically significant difference in mean scores for planning (M =0.37, S.D = 0.27) and reasoning (M= 0.59, S.D = 0.22, $p < 0.05$), with reasoning task more proficient that the planning task which was quite low in proficiency. There was however, no statistically significant difference in mean scores of performing and reasoning tasks.

Table 18: *Analysis of Variance (ANOVA) results on Reflection with respect to planning, performing and reasoning.*

Source	Df	Sum of Square	Mean Square	F	P	Eta Squared
Between Groups	2	4.292	2.146			
Within Groups	339	22.112	0.065	32.898	0.01	0.16
Total	341	26.406				

Significant p<.05

Note: Effect size (Eta Squared) reflects the proportion of variance in dependent variables that is associated with independent variable.

Table 18 shows one-way between groups analysis of levels of elective physics students in science process skills of planning, performing and reasoning. Post-hoc comparisons using the Tukey HSD test indicated that the mean score for planning task test (M= 0.37, S.D = 0.27) was significantly different from performing (M = 0.61, S.D = 0.28), with performing task being more proficient. Again planning task (M = 0.37, S.D = 27) and reasoning tasks (M = 0.59, S.D = 0.22), are statistically significant, with the latter more proficient than the former. . There was no statistically significant difference between performing task (M = 0.61, S.D = 0.28) and reasoning task (M = 0.59, S.D = 0.22).

Table 19 presents the *means for groups in homogeneous subsets for reflection tasks.*

Table 19: *Post-Hoc comparing means among groups in homogeneous subsets for Reflection Tasks*

(I) Task refraction	(J) Task	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Planning	Performing	-.24708*	.3383	.000	-3267	-.1674
	Reasoning	-.22690*	.3383	.000	-3065	-1473
Performing	Planning	.24708*	.03383	.000	.1674	.3267
	Reasoning	.02018	.03383	.822	-.0595	.0998
Reasoning	Planning	.22690*	.03383	.000	.1473	.3065
	Performing	-.02018	.03383	.822	-0998	.0595

The mean difference is significant at the 0.05 level

This study agreed with Ossei-Anto (1996) that planning tasks was the lowest in proficiency level. This outcome could be explained due to the fact that, during most practical work in a Ghanaian physics laboratory setting, students are normally given procedure/steps to follow in carrying out experiments (Cornah, 2016). Hence science processes skills of planning are not normally developed due to lack of practice under expert guidance.

Differences in the Proficiency Levels of Male and Female Physics Students' Science Process Skills in Refraction Tasks

Hypothesis three sought to test whether there is statically significant difference in the proficiency levels of male and female physics students in science process skills (planning, performing and reasoning) in refraction. To fulfil this purpose, MANOVA was used to compare the mean scores of male and female physics students in planning, performing and reasoning (i.e., dependent variables) for refraction tasks (i.e., independent variable).

Before this, preliminary screening was done to test the assumption that the samples across the two groups (i.e., male and female) were equivalent in their planning, performing and reasoning science process skills and also test the assumption for normality, linearity and multicollinearity, multivariate outliers and multivariate normality, homogeneity of covariance matrices and test of equality of error variance. It was observed that there were no violations [Appendix E].

Table 20 shows the summary of MANOVA results for male and female physics students in planning, performing and reasoning tasks for refraction. The Pillai's Trace was used to evaluate the MANOVA differences. As shown in Table 19, there was no statistically significant difference in mean scores between male and female students in planning, performing and reasoning (i.e., combined dependent variables) for refraction tasks: $F(1, 139) = .402$, $p = .752$, *Pillai's Trace* = .009. Pillai's Trace is used as a test statistic in MANOVA. This is a positive valued statistic ranging from 0 to 1. Increasing values means that effects are contributing more to the model, hence the null hypothesis is rejected for large values, hence in this case the value is very small hence the null hypothesis cannot be rejected. This means male and female physics students demonstrated the same proficiency levels in planning, performing and reasoning science process skills with respect to refraction tasks.

Table 20: *Summary of MANOVA for male and female physics students in planning, performing and reasoning for refraction tasks*

Dependent Variables	Multivariate F	Pillai's Trace	df	p
Planning				
Performing	.402	.009	1, 139	.752
Reasoning				

Not Significant, since $p > .05$

On the other hand Ossei-Anto (1996) who did a similar study in the U.S.A had different findings where, there was no significant difference between males and females in the tasks of performing and reasoning skills. There was a difference in planning task between males and females.

Hands-on activities attract students' interest and enhance their motivation. From data gathered from the opinionnaire responded to by the respondents, it seems that most of the physics teachers in the schools used for the study were using the traditional way of lesson delivery; more of the lecture approach with little on hands-on activities (Byzee, Trowbridge, and Powell, 2008).

It is important to note that laboratory skills and science process skills cannot be developed just by transmitting the body of knowledge without laboratory – centered inquiry activities.

Differences in the Proficiency Levels of Male and Female Physics Students' Science Process Skills in Reflection Tasks

Hypothesis four sought to test whether there is a statistical significance difference in the proficiency level of male and female physics students in only. Performing and reasoning they were at the same proficiency level for both male and female.

Table 22 shows the summary of MANOVA results for male and female physics students in planning, performing and reasoning tasks for reflection tasks. The Pillai's Trace was used to evaluate the MANOVA differences.

Table 22: *Summary of MANOVA for male and female physics students in planning, performing and reasoning tasks for Reflection*

Dependent Variables	Multivariate F	Pillai's Trace	df	p
Planning				
Performing	1.764	.046	1, 112	.158
Reasoning				

Not Significant, since $p > .05$

As shown in Table 21, there was no statistically significant difference in mean scores between male and female students in planning, performing and reasoning (i.e., combined dependent variables) for reflection tasks: $F(1, 112) = 1.764, p = .158$, *Pillai's Trace* = .046.

This means male and female physics students demonstrated the same proficiency levels in planning, performing and reasoning science process skills with respect to reflection tasks.

The finding that there was no significant gender difference in the performance is consistent with the finding in some other countries (Greenfield, 1996). The researcher could not explain the likely reason for this finding based on this study's data alone; excepts that one can say that it may due to lack of frequent hands-on activities.

Differences in the Proficiency Levels among Boys only, Girls only and Mixed School-type Physics Students' Science Process Skills in Refraction Tasks

Hypothesis five sought to test whether there is statistically significant difference in the proficiency levels of science process skills (planning, performing and reasoning) in refraction with respect to school – type (male only, female only, or mixed. To fulfill this purpose, MANOVA was used to compare the mean scores among boys only, girls only and mixed school-type students in planning, performing and reasoning (i.e., dependent variables) for refraction tasks (i.e., independent variable).

Before this, preliminary screening was done to test the assumption that the samples across the two tasks (i.e., boys only, girls only and mixed school-type) were equivalent in their planning, performing and reasoning science process skills and also test the assumption for normality, linearity and multicollinearity, multivariate outliers and multivariate normality, homogeneity of covariance matrices and test of equality of error variance. It was observed that there were no violations [Appendix E].

Table 23: *Means and Standard Deviations for boys only, girls only and mixed school-type students in planning, performing and reasoning for refraction tasks*

Dependent Variable		Boys only (N=40)	Girls only (N=59)	Mixed (N=42)
Planning Task	Mean	.53	.45	.19
	SD	.30	.28	.16
Performing Task	Mean	.35	.35	.32
	SD	.28	.28	.30
Reasoning Task	Mean	.76	.66	.51
	SD	.22	.26	.30

Maximum score 1.00

Table 23 presents the descriptive statistics for boys only, girls only and mixed school-type students in planning, performing and reasoning tasks for refraction. As shown in Table 23, the mean scores for boys only, girls only and mixed school-type students in planning (Boys only = .52, Girls only = .45 and Mixed = .19) and reasoning (Boys only = .76, Girls only = .66 and Mixed = .15) tasks were relatively different with those of performing (Boys only = .35, Girls only = .35 and Mixed = .32) were relatively similar.

Table 24 shows the summary of MANOVA results for boys only, girls only and mixed school-type students in planning, performing and reasoning for refraction tasks. The Pillai's Trace was used to evaluate the MANOVA differences.

however, no statistically significant difference in mean scores for performing task: *F*(2, 138) = 9.316, *p* = .866.

Table 25 shows the summary of ANOVA results for Refraction Task for Boys only, Girls only and Mixed school -types

Table 25: *Summary of (ANOVA) results on planning, performing and reasoning skills among boys only, girls only and mixed school-type students for refraction tasks*

Dependent variable	Univariate F	df	p	Partial Eta Squared
Planning	18.847	2, 138	.0010*	.22
Performing	.145	2, 138	.866	
Reasoning	9.316	2, 138	.0010*	.12

*Significant, since $p < .05$

Post-hoc comparisons using the Tukey HSD test as shown in Table 25 indicated that there was a statistically significant difference in mean scores for planning task between boys only schools (M=.53, SD=.30) and mixed schools (M=.19, SD=.16, p <.05). Students from the Boys only schools outperformed their counterparts in the mixed schools on planning task. There was also a statistically significant difference in mean scores for planning task between girls only schools (M=.45, SD=.28) and mixed schools (M=.19, SD=.16, p <.001). Students from the girls only schools outperformed their counterparts in the mixed schools on planning task. There was, however, no statistically significant difference in mean scores for planning task between boys only schools (M=.53, SD=.30) and girls only schools (M=.45, SD=.28, p = .379). As shown in Table 25, there was, a statistically significant difference in mean scores for reasoning task between boys only schools (M=.76, SD=.22) and mixed schools (M=.51, SD=.30, p <.05). Students from the boys only schools outperformed their counterparts in the mixed schools on reasoning task. There was also a statistically significant difference in mean scores for reasoning task between Girls only schools (M=.66, SD=.26) and mixed schools (M=.51, SD=.30, p =.016). Students from the girls only schools outperformed their counterparts in the mixed schools on reasoning task. There was, however, no statistically significant difference in mean scores for reasoning task between boys only schools (M=.76, SD=.22) and girls only schools (M=.66, SD=.26, p = .161).

Table 26 Post Hoc comparison among boys only, girls only and mixed school-type students for planning and reasoning tasks for refraction

Table 26: *Post-Hoc comparison among boys only, girls only and mixed school-type students for planning and reasoning skills for refraction tasks*

Dependent Variable	i	j	p
Planning	Boys only	Girls only	.379
		Mixed	.010*
	Girls only	Mixed	.010*
Reasoning	Boys only	Girls only	.161
		Mixed	.010*
	Girls only	Mixed	.016*

Differences in the Proficiency Levels among Boys only, Girls only and Mixed School-type Physics Students' Science Process Skills in Reflection Tasks

Hypothesis six sought to test whether there is a statistically significant difference in the proficiency levels of science process skills (planning, performing and reasoning) in reflection with respect to school-type (male only, female only, or mixed) . To fulfill this purpose, a three- way MANOVA was used to compare the mean scores among boys only, girls only and mixed school-type students in planning, performing and reasoning (i.e., dependent variables) for reflection tasks (i.e., independent variable).

Before this, preliminary screening was done to test the assumption that the samples across the two tasks (i.e., boys only, girls only and mixed school-type) were equivalent in their planning, performing and reasoning science process skills and also test the assumption for normality, linearity and multicollinearity, multivariate outliers and multivariate normality, homogeneity of covariance matrices and test of equality of error variance. It was observed that there were no violations [Appendix E].

Table 27 presents the descriptive statistics for boys only, girls only and mixed school-type students in planning, performing and reasoning tasks for reflection. As shown in Table 28, the mean scores for boys only, girls only and mixed school-type students in planning (Boys only = .34, Girls only = .53 and Mixed = .23), performing (Boys only = .65, Girls only = .67 and Mixed = .52) and reasoning (Boys only = .61, Girls only = .63 and Mixed = .53) were relatively different.

Table 27: *Means and Standard Deviations for boys only, girls only and mixed school-type students in planning, performing and reasoning skills for reflection tasks*

Dependent Variable		Boys only (N=39)	Girls only (N=38)	Mixed (N=37)
Planning Task	Mean	.34	.53	.23
	SD	.26	.24	.23
Performing Task	Mean	.65	.67	.52
	SD	.23	.27	.30
Reasoning Task	Mean	.61	.63	.55
	SD	.19	.23	.23

Table 28 shows the summary of MANOVA results for boys only, girls only and mixed school-type students in planning, performing and reasoning tasks for reflection tasks. The Pillai's Trace was used to evaluate the MANOVA differences.

Table 28: *Summary of MANOVA for boys only, girls only and mixed school-type students in planning, performing and reasoning skills for reflection tasks*

Dependent Variables	Multivariate F	Pillai's Trace	df	p	Partial Eta Squared
Planning Performing Reasoning	4.755	.230	2,111	.0010*	.12

Significant, since $p < .05$

As shown in Table 28, there was a statistically significant difference in mean scores among boys only, girls only and mixed school-type students in planning, performing and reasoning (i.e., combined dependent variables) for reflection tasks: $F(2, 111) = 4.755, p < .001$, *Pillai's Trace* = .230, *partial eta squared* = .12. This means boys only, girls only and mixed school-type students demonstrated different proficiency levels in planning, performing and reasoning science process skills with respect to reflection tasks.

Table 29: *ANOVA results on planning, performing and reasoning skills among boys only, girls only and mixed school-type students for reflection tasks*

Dependent variable	Univariate F	df	p	Partial Eta Squared
Planning	14.035	2, 111	.001*	.20
Performing	3.242	2, 111	.043*	.06
Reasoning	1.286	2, 111	.280	

*Significant, since $p < .05$

Furthermore, the results of a follow-up univariate ANOVA tests to check the between-subject effects for planning, performing and reasoning skills among boys only, girls only and mixed school-type students for reflection tasks, which is presented in Table 29, and indicate that the only difference in mean scores to reach statistical significance, using the Bonferroni adjusted alpha level of .016, were planning skills: $F(2, 111) = 14.035, p < .001$ whose effect accounted for 20% of the variance in planning skills for reflection [partial eta squared = .20] and performing skills: $F(2, 111) =3.242, p = .043$ whose effect accounted for 6% of the variance in reasoning skills for refraction [partial eta squared = .06]. As shown in Table 29, there was, however, no statistically significant difference in mean scores for reasoning task and performing task: $F(2, 111) = 1.286,\ p = .280$.

Post-hoc comparisons using the Tukey HSD test as shown in Table 30 indicated that there was a statistically significant difference in mean scores for planning task between boys only schools (M=.34, SD=.26) and girls only schools (M=.53, SD=.24, p =.003). Students from the girls only schools outperformed their counterparts in the boys only schools on planning task. There was also a statistically significant difference in mean scores for planning task between girls only schools (M=.53, SD=.24) and mixed schools (M=.23, SD=.23, p <.001). Students from the girls only schools outperformed their counterparts in the mixed schools on planning task. There was, however, no statistically significant difference in mean scores for planning task between boys only schools (M=.34, SD=.26) and mixed schools (M=.23, SD=.23, p = .193).

As shown in Table 28, there was no statistically significant difference in mean scores for performing task between boys only schools (M=.65, SD=.23) and girls only schools (M=.67, SD=.27, p =1.000). There was also no statistically significant difference in mean scores for performing task between boys only schools (M=.65, SD=.23) and mixed schools (M=.52, SD=.23, p =.113). There was no statistically significant difference in mean scores for performing task between girls only schools (M=.67, SD=.27) and mixed schools (M=.52, SD=.23, p = .069).

Table 30: *Post- Hoc comparison among boys only, girls only and mixed school-type physics students for planning, performing and reasoning skills for reflection tasks*

Dependent Variable	i	j	p
Planning	Boys only	Girls only	.003*
		Mixed	.193
	Girls only	Mixed	.010*
Performing	Boys only	Girls only	1.000
		Mixed	.113
Reasoning	Girls only	Mixed	.069

Where i and j represent school type

Students from boys only and girls only out-performed the counterparts from the mixed schools on reasoning science process skills. There was no significant difference between boys only and girls only on reasoning. Girls only schools out-performed boys only and mixed schools in planning skills. Boys only and mixed schools had no statistically significant difference. On performing skills there was no statistically significant difference among boys only, girls only and mixed schools. There are studies that demonstrate that single-sex schools are better at achieving higher academic levels (Dhindsa & Chung, 2003). The study tends to confirm the assertion by the researchers. On the other hand the respondents irrespective of the school-type were all at the same level of proficiency in skills performing and this could be due to the evidence provided in the opinionnaire in the various institutions. It seems the physics theory was focused on at the lower levels (i.e. form one and two) at the detriment of failing to develop the students science process skills.

Table 33: *ANOVA Results for Tasks A and Tasks B by Gender*

	Tasks A		Tasks B	
Task	F	Sig of F	F	Sign of F
Task 1	13.09	.001*	3.25	0.030**
Task 2	0.61	0.611	1.24	0.306
Task 3	6.27	.010*	1.82	0.149
Tasks A:	Df = 1; 140	Tasks B:	Df = 1; 113	

From Table 33, Tasks A sample, that is students who did refraction of light tasks, there is a significant difference in tasks A_1, planning skills between boys and girls. From Tasks B sample, that is students who did reflection of light tasks, there seems to be a significant difference in tasks B1, planning skills between boys and girls.

Students Comments on the Performance Tasks (for Time provided and Difficulty levels)

The student opinionnaire (Appendix B1), which were administered after the completion of the performance tasks, asked for the student's opinion on various aspects of the tasks (i.e. time provided and task difficulty level) they had performed.

Table 34 shows the distribution of sample by time provided for Task A_1 and B_1.

From Table 35 on the issue of time provided, 71.6% (task A) and 66.7% (task B) said the time provided was about right, 9.9% (task A) and 7.9 (task B) indicated that the task was difficult. The rest did not provide a response or indicated that the time was too much.

Table 36 shows the distribution of sample for time provided for Task A_3 and Task B_3.

Table 36: *Distribution of sample for Time provided for Task A_3 and Task B_3 (Reasoning skills)*

Time	Task A_3		Task B_3	
Provided	Frequency	Percentage	Frequency	Percentage
No Answer	3	2.1	5	14.4
Not Enough	13	9.2	20	17.5
About Right	100	70.9	77	67.5
Too Much	25	17.7	12	7.4

N = 141

From Table 36, on the issue of time provided, 70.9% (task A) and 67.5% (task B) indicated that the time provided was about right, 9.2% (task A) and 17.5% (task B) indicated that the time was not enough. In task A, a significant percentage 17.4% indicated that the time was too much.

Table 37 shows that distribution of item difficulty for Task A_1 and B_1. From Table 37, on the issue of item difficulty, 46.1% (task A) and 65.8% (task B) indicated it was about right. 31.9% (task A) and 23.7% (task B) said it was difficult and the rest did not respond or indicated it was easy.

indicated that it was easy and the rest did not respond or indicated it was difficult.

Table 39 shows the distribution of items difficulty for Task A_3.

Table 39: *Distribution of Item difficulty for Task A_3 and Task B_3 (Reasoning skills)*

Item Difficulty	Task A_3 Frequency	Percentage	Task B_3 Frequency	Percentage
No Answer	5	3.5	6	5. 3
Easy	59	41.8	38	33.3
About Right	73	51.9	66	57.9
Difficult	4	2.8	4	3.5

N = 141

Table 39 on the issue of item difficulty level, 51.9% (tasks A) and 57.9% (tasks B) indicated it was about right. 41.8% (task A) and 33.3% (task B) indicated it was easy and the rest either did not respond or indicated that it was difficult.

Table 40 shows the distribution of Tasks A by item difficulty levels.

Table 40: *Distribution of Tasks A Items by Difficulty Levels*

Component Assessed	Difficulty Level (Tasks A)
1. General strategy	0.82
2. Sequential plan	0.49
3. Detailed plan	0.23
4. Workable plan	0.16
5. Appropriate diagram	0.37

Component Assessed	Difficulty Level (Task A)
6. Accurate value of i_A	0.61
7. Additional accurate value of i_A	0.30
8. Accurate measurements from sheet	0.55
9. Accurate value of r_A	0.13
10. Accurate measurement from sheet	0.49
11. At least two correct values of Sin i &Sin r	0.13
12. Accurate value of f.	0.16
13. One or two accurate values of u.	0.80
14. Additional one/two values of u.	0.79
15. One or two values of v.	0.87
16. Additional one/two accurate values of v.	0.74
17. At least two accurate values of $\frac{1}{u}$	0.71
18. At least two accurate values of $\frac{1}{v}$	0.65
19. At least two accurate values of $\frac{1}{f}$	0.59
20. At least two accurate f values.	0.58
21. Accurate or appropriate sources of error	0.19

Total number of components/items assessed = 22

Table 41 shows the distribution of Tasks B Items by difficulty levels.

Table 41: *Distribution of Tasks B Items by Difficulty Levels*

Component Assessed	Difficulty Level
1. General strategy	0.77
2. Sequential plan	0.52
3. Detailed plan	0.28
4. Workable plan	0.07
5. Appropriate diagram	0.17
6. Safety procedure	0.39
7. Accurate value of images at 120^0	0.79
8. Accurate value of images at 90^0	0.79
9. Accurate value of images at 72^0	0.74
10. Accurate value of images at 60^0	0.62
11. Accurate appearance of images seen	0.70
12. Accurate pattern/trend of no. of images	0.41
13. Appropriate safety procedure	0.25
14. One or two accurate values of u.	0.89
15. Additional one/two values of u.	0.88
16. One or two values of v.	0.88
17. Additional one/two accurate values of v.	0.87
18. At least two accurate values of $\frac{1}{u}$	0.91
19. At least two accurate values of $\frac{1}{v}$	0.26
20. At least two accurate values of $\frac{1}{f}$	0.22
21. At least two accurate values of 'f'.	0.19
22. Accurate or appropriate sources of error	0.33

Total number of components assessed = 22

Doran's (1980) Item Categorization as cited by Ossei-Anto (1996).

Item Difficulty Levels

Very Easy	(0.85 - 1.00)
Moderately	(0.60 - 0.85)
Moderately Difficult	(0.35 – 0.60)
Very Difficulty	(0.00 – 035)

According to the categorization above, for both tasks and their difficulty levels; tasks A and tasks B had comparable results shown as shown in table 40 and table 41.

Table 42 shows the number of hours of practical work within 2 weeks for tasks A.

Table 42: *Number of Hours of Practical work within 2 Weeks for Tasks A(N=110)*

Number of Hours	Frequency	Percentage
Did not respond or no practical	65	59.1
1	15	13.6
2	17	15.5
3	7	6.4
4	3	2.7
6	1	0.9
10	1	0.9
16	1	0.9

Table 43 shows the number of hours practical work done by students within two weeks for Tasks B

Table 43: *Number of Hours of Practical work within Two Weeks for Tasks B*

Number of Hours	Frequency
Did not respond or no practical	54
1	4
2	7
3	1
4	6
6	1

N = 88; supposed to be 114

Sample Weekly Practical work done by Schools for Tasks A and Tasks B

School 1

Tasks A Sample

1. Once a week
2. Twice
3. An hour
4. About six hours a week
5. 3 hours 10min.

Tasks B Sample

1. Twice
2. 4 hours
3. 3 hours 30 min.
4. 2 hours 20min.
5. Enough time

School 2

Tasks A Sample

1. About three times a term
2. Twice
3. 4 hours
4. I spend no time doing physical practical
5. Rarely once

Tasks B Sample

1. Once
2. Once in a while
3. 2 hours
4. 2 hours 45 min.
5. Twice

School 3

Tasks A Sample

1. We don't get time to perform any physics practical work.
2. We hardly do any.
3. We hardly have physics practical in school.
4. Very rare, sometime twice in a term or none.
5. 40 or 50 minutes is spent doing physics practical

Tasks B Sample

1. None
2. Once
3. None. Haven't performed any since form one
4. Nil

5. 3 hours or 45 minutes.

School 4

Tasks A Sample

1. Not enough time
2. None
3. Only once since form one
4. Sometimes none
5. We have not done any practical yet.

Tasks B Sample

1. Not often. At least 3 times in a term.
2. At least once.
3. We hardly have physics practical work.
4. A term no practical
5. Most a time we don't do any practical.

School 5

Tasks A Sample

1. Once in a blue moon
2. We hardly do physics practical.
3. Not at all
4. 2 hours
5. 2 hours per week.

Tasks B Sample

1. It is barely done.
2. Sometimes once or none.
3. Rare/seldom done in a week.

4. 2 hours on Mondays.
5. 105 minutes a week.

School 6

Tasks A Sample

1. None, but as a class, 40mins in a term and then end of term exams.
2. About 2 times a term.
3. About 2 times a term.
4. Once or at least twice in a term before our exams.
5. Less than 2 hours.
6. There is not much time to do physics practical.

Tasks B Sample

1. Once in a blue moon.
2. None
3. Once a term.
4. Not often
5. Zero (o)

School 7

Tasks A Sample

1. We do not have time to do physics practical in school.
2. 20 minutes.
3. Not frequently in every two weeks.
4. Not more than one, sometimes none.
5. We don't do it frequently, once in a term.

Task B Sample

1. Once in a blue moon.
2. Nil
3. Seven times
4. We seldom do physics practical.
5. We don't spend much time doing physics practical.

Time Allocated for Practical Work as noted from the Study by Students

From the study it was discovered that time allocated for practical work varied from school to school. In some schools the periods for physics practical work was put on the time table, others were not and hence you could see from one school, sample in the same form having different values. This meant that teachers conducted practical work at their convenience when very necessary. Some sample commented that teachers normally use the practical period to do theoretical physics in order to complete the syllabus on time.

Some schools refuse to take elective physics students form 1 and form 2 through physics practical work because they think that a lot of theory should be done before engaging the students in any practical activity. Others also think that once the students get to form three, they will be taken through a lot of practical work to cover all that they were to have done in form 1 and form 2. WAEC physics practical are done at the end their final years (3^{rd}) only; no other practical examination.

From the questionnaire responses physics practical activities were not conducted very effectively and regularly for the sample in the schools selected for this study. From the students questionnaire, quite a number of respondents indicated that they never did any practical work in an entire term presents evidence to confirm the WAEC Chiefs' reports over the years in physics practical examinations showing that students inabilities in the practical activities during exams were due to the fact that they were not taken through the practical work they were supposed to have done.

In Ghana, there is a strong requirement for practical work in general science at the senior high school levels. This is because both the Ministry of Education and West African Examination Council syllabi stress practical work as examinable. Some of the aims of the SHS physics syllabus are the development of behaviours, attitudes, values, skills as well as knowledge acquisition.

In summary, there was clear evidence from the students' opinionnaire that practical activities were not organized regularly at the lower forms (i. e, 1 and 2). Thus the students have not developed high levels of proficiencies in science process skills of planning, performing and reasoning.

Students Comments from Opinionnaire on how Tasks could be revised to make them better

On the above question, three clear directions came up which are the tasks must be taken frequently, is appropriate hence no need for revision and tasks be made clearer with additional time added.

Below are some of the comments by students according to the tasks they took:

Tasks A Sample

1. I think you should make this exercise regularly for us to know our abilities.
2. If we can be given regularly.
3. It should be done every term and more questions should be added.

4. By ensuring that such test should by really encouraged.

Tasks B Sample

1. Assessment such as these should be frequently held.
2. Do for other topics as well.
3. Making them regular.
4. Should be done more often.

Appropriate tasks, no need for revision

Tasks A Sample

1. I think is very fine and a great job.
2. I think the task is okay and appropriate.
3. I wish it will be done this way.
4. Appropriate and if we can be given regularly.

Tasks B Sample

1. Learning adequately.
2. 100% recommended.
3. They should be a website for students to visits during vacations.
4. Appropriate, but add other topics as well.

Tasks be made clearer/additional be added

Tasks A Sample

1. Tasks should be made clearer.
2. Make tasks more practical.
3. A little more time should be added.
4. Tasks must be more specific on the number of answers a student must provide.

Tasks B Sample

1. Tasks should be made easier to understand.
2. Tasks must be made a little clearer.
3. Increase the time for the work.
4. Tasks should be framed in a more understandable ways for students.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Overview

In this concluding chapter, the key findings of the study are presented. This study assessed the level of proficiency of Form 2 SHS General Science students offering elective Physics in Cape Coast Metropolis in demonstrating science process skills of planning, performing and reasoning in two subtopics in optics-refraction and reflection using performance assessment tasks.

Summary

From the results in chapter four, it can be said that the items in the performance tasks (A and B) (i.e. planning, performing and reasoning) were not too easy or too difficult, they were moderate and this was seen from the pattern of responds from the students opinionnaire. The items were at different levels of difficulty and time allocated was adequate. Quite a few of the items on the performance tasks were very difficult or moderately easy. Majority of the items were about right (i.e. either moderately difficult or moderately easy). The respondents of this study in both tasks A and tasks B appeared to have had some challenges with the tasks that they took in Task$_1$, Task$_2$ and Task$_3$ of both Tasks A and Tasks B results; poor measuring skills, and it may be due to lack of adequate laboratory practice in the physics classes and laboratories in their schools.

The study tested the following six null hypotheses at 0.05 level of significance:

1. There is no statistically significant difference in the proficiency level in students' science process skills (planning, performing and reasoning) in refraction and reflection.
2. There is no statistically significant difference in the proficiency levels of male and female physics students in science process skills (planning, performing and reasoning) in refraction.
3. There is no statistically significant difference in the proficiency level of male and female physics students in science process skills (planning, performing and reasoning) in reflection.
4. There is no statistically significant difference in the proficiency levels in students science process skills (planning, performing and reasoning) in refraction with respect to school-type (male only, female only or mixed).
5. There is no statistically significant difference in the proficiency levels of students in science process skills (planning, performing and reasoning) in reflection with respect to school-type (male only, female only or mixed).

In all, 255 Form 2 students sampled from seven out of ten senior high schools offering physics, chemistry, biology and mathematics as electives in the Cape Coast Metropolis participated in the study.

The study adopted a cross-sectional survey design. The psychometric testing approach adapted from an earlier work done by Ossei-Anto (1996) in the U.S.A was employed as the main instrument. Sample of 40 students from each school were randomly grouped into two for either all the three tasks in refraction (Tasks A) or reflection (Tasks B)-**not both.**

The study used a combination of quantitative research method and a opinionnaire to collect data. The quantitative data consisted of the tasks A (Refraction: planning, performing and reasoning) and tasks B (Reflection: planning, performing and reasoning) which were analyzed using frequencies and percentages, means scores, ANOVA and MANOVA. The opinionnaire responses consisted of reasons students provided after completing the tasks at the end, of the tasks on items difficulty and the time provided. These answers provided insight into the difficulty levels of the tasks, the amount of time provided for each task, as well as any suggestion for the improvement of the tasks.

Key Findings

The analysis of the results gave the following key findings:

1. Research question

Planning Tasks for Refraction and Reflection:

i. Except for general strategy there were low proficiency levels in both planning skills for tasks in refraction and reflection.

Performing Tasks for Refraction and Reflection:

ii. Most of the students could not measure the angles of the images produced by the rectangular glass block.

iii. Majority of the students could handle the images produced or formed by the inclined plane mirrors, however quite a number of the students could not hand the trend or pattern formed by the images in the inclined plane mirrors.

iv. Most of the students showed high level of proficiency in measuring distance and recording data in tabular form, and computing of the reciprocals of v and f. However, most students could not provide appropriate sources of error.

v. Most of the students exhibited satisfactory levels of proficiency in measuring distances and recording data in tabular form. However, most students could not compute the values of the reciprocals of v and f, and also provide appropriate sources of error.

2. Hypothesis one

i. Analysis of students' means scores in refraction tasks for planning, performing and reasoning using ANOVA showed that there was statistically significant difference in mean scores in refraction tasks for planning, performing and reasoning. This means that students demonstrated different proficiency levels in planning, performing and reasoning in science process skills with respect to refraction tasks.

ii. Comparing of students refraction mean scores to planning, performing and reasoning skills were analyzed using ANOVA indicate that the only difference in mean scores to reach significance was reasoning skills. This finding imply that the null hypothesis one of no statistically significant difference in the proficiency levels of physics students science process skills in refraction (planning, performing and reasoning) was rejected since proficiency levels were different.

3. Hypothesis two

   Analyses of the mean scores for male and female physics students in refraction (planning, performing and reasoning) using a two-way MANOVA showed that both male and female students were equivalent or at the same levels of proficiency. These finding imply that the null hypothesis three of no statistically significant difference in the proficiency levels of male and female physics students' science process skills in refraction was confirmed.

4. Hypothesis three

   Evaluating the MANOVA differences of male and female physics students in planning, performing and reasoning tasks for refraction showed no statistically significant difference in mean scores between male and female students in planning, performing and reasoning. This means that male and female physics students demonstrated planning, performing and reasoning in science process skills with respect to reflection tasks.

   These finding imply that the null hypothesis three of no statistically significant difference in the proficiency levels of male and female physics students' science process skills in refraction was confirmed.

5. Hypothesis four

i. Analysis of the mean scores for male and female physics students in reflection (in planning, performing and reasoning) using a two-way MANOVA showed that both male and female students have no statistically significant difference in process skills of planning, performing and reasoning. This means male and female physics students are at the same levels of proficiency.

ii. Evaluating the MANOVA difference of male and female physics students in planning, performing and reasoning tasks for reflection showed no statistically significant difference in mean scores between male and female students in planning, performing and reasoning. This means that male and female physics students demonstrated the same proficiency levels in planning, performing and reasoning in science process skills with respect to reflection tasks.

6. Hypothesis five

i. Analysis of the mean scores for boys only, girls only and mixed school-type in science process skills (planning , performing and reasoning) in refraction using a three way MANOVA showed that the was a statistically significant difference in the levels of proficiency. This indicated that there was a statistically significant difference in the scores for planning, task between boys only schools and girls only and mixed schools. Students from the boys only schools outperformed their counterparts in the mixed schools and girls only schools on planning tasks. Students from the girls only schools outperformed their counterparts in the mixed schools on planning task.

ii. There was, however, no statistically significant difference in mean scores for planning tasks between boys only and girls only schools. Students from boys only school outperformed their counterparts in the mixed schools on reasoning tasks.

iii. There was also a statistically significant difference in mean scores for reasoning task between girls only schools and mixed schools. Students from the girls only schools outperformed their counterparts in the mixed schools on reasoning task.

iv. There was however, no statistically significant difference in mean scores for reasoning task between boys only schools and girls only schools.

7. Hypothesis six

i. Analyses of the mean scores for boys only, girls only and mixed school-type in science process skills (planning, performing and reasoning) in reflection using a three way MANOVA showed that there was a statistically difference in mean scores among boys only, girls only and mixed school-type students in planning, performing and reasoning. There was however, no statistically significant difference in mean scores for reasoning task. There was statistically significant difference in mean scores for planning task between boys only schools and girls only schools outperformed their counterparts in the boys only schools on planning task.

ii. There was statistically significant difference in mean scores for planning task between girls only schools and mixed schools. Students from the girls only schools outperformed their counterparts in the mixed schools.

iii. There was however, no statistically significant difference in mean scores for planning task between the girls only and boys only schools.

iv. There was no statistically significant difference in mean scores for performing task between boys only schools and girls only school.

v. There was no statistically significant difference in the mean scores for performing task between boys only schools and mixed schools.

vi. There was no statistically significant difference in mean scores for performing task between girls only schools and mixed schools.

The results in the study showed some inadequacies due to lack of proficiency in laboratory skills by a number of respondents. The classification of sample according to the special factors of gender and school type to predict achievement were quite effective and useful for both Tasks A and Tasks B. Significant relationships between gender and school type in relation to performance tasks, Tasks A and Tasks B were obtained.

the back of a student's mind to provide safety tips/hints to guide one to the right solution of the problem.

Performing skills

Under performing skills, three items were poorly attempted. Two of the items recorded the same percentage of 13.0% full credit by sample. These two items were the poorest. The students were not able to obtain the accurate values of the r_A, the refracted angles as well as the Sin i and Sin r values during the exercise. The simple reason for the above outcome was that they did not often engage then in any practical work in physics at most of their schools as indicated by the responses to the opinionnaire (see Appendices B & C).

The third inadequate item was the students' inability to determine focal length of the equipment they used. Again the reason was not far-fetched, they were not taken through any practical work in physics; they were only doing the theory part of the physics syllabus, including using the period allocated to practical work for theory.

Reasoning skills

There was only inadequate performance exhibited by students in tasks A_3 that is on accurate/appropriate sources of error. Only 19.0% obtained full credit and many as, 81.0% got the item wrong. This section had the procedure as taking some measurement and then computing the results. Most students handled the work theoretically. They did not go through practical activities, hence could not come out with the sources of error. Again it bores down to their lack of practical work exposures.

Tasks B for Sample

Planning skills

Under planning skills three items performed poorly or were inadequately done. Again the poorest item was detailed plan, only 7.0% had full credit, with 93.0% getting it wrong; followed closely was their ability to provide an appropriate diagram for the work. Here most of the students were not sure of what was expected of them. The third inadequate item handled was detailed plan with 28.0% receiving full credit and 72.0% had the answers wrong. The reasons for these trends is the same as provided for tasks A; no provision is made for development of planning skills in elective physics at the SHS level in Ghana.

Performing skills

Tasks B performing skills, items were well handled by students, only one item had an inadequate performance exhibited, appropriate safety procedure, only 25.0% had full credit and 75.0% had it wrong. This trend can be attributed to their lack of frequent use of the laboratory or classroom for practical purpose and hence either they do not know or they had not treated the topic practically.

Reasoning skills

There were four major inadequacies in performance on the reasoning skills in Tasks B. The first and the poorest was on the inability of sample to determine accurately the focal length of the equipment used. I am sure some could not tackle the item because, the first time they handled the equipment was the day the study was conducted; lack of practice in practical skills by students at their schools.

The second inadequate proficiency was the inability of students' to determine the values of $\frac{i}{f}$, 22.0% full credit and 78.0% had it wrong. In fact the students needed to determine: $\frac{i}{f}$, using $\frac{i}{u}+\frac{i}{v}$ but there are (-ve or +ve) signs to be added in the procedure, which most of the students ignored. Again this was the result of lack of practical exposure and regular constant practice. The third inadequacy was in the students' inability to determine $\frac{i}{v}$ 26.0% full credit and 74.0% had it wrong. Here depending on the positioning of the image (whether erect or inverted) a positive (+) or a negative (-) sign had to be added, students ignored that principle hence performed poorly.

The fourth inadequacy in performance was on appropriate sources of error, 33.0% had full credit and 67.0% got it wrong. This trend is due to real practical work in elective physics in the laboratories of school. In fact going through both tasks A and tasks B, two items that consistently perform poorly were lack of safety precautions and appropriate/accurate sources of error. These are very important steps in carrying out any meaningful effective practical work, not only in elective physics but all the other science subjects at the SHS level. Effort should be made to drum home the importance of these two indispensable steps and procedures into our practical activities and works. Physics teachers need to encourage/caution physics students to always come up with safety precautions and sources of error during their practical activities in the laboratories/classroom.

In the course of administration of the tasks the researcher noticed that students had difficulty recording lengths accurately without approximating, which was unacceptable in the study. Students need to be assisted to be very accurate in measurement when collecting data. In fact precision in measuring should be stressed and taught thoroughly and painstakingly in the senior high school science programme.

The modal age of sample for both Tasks A and Tasks B was 17 years, with percentage of 52.94%, followed by age 16, with a percentage of 32.94 and 18 years were 10.20%, the others were not significant, 15, 19 and 20, were all together less than 7.0%, it is worth noting that a further research can include the age parameter for investigation. The design and development of the new instrument to assess the science process skills of students in senior high school elective physics in optics seems to have been quite satisfactory and clearly carried out. The item analyses: frequencies, percentages, correlation, mean scores, ANOVA and MANOVA exhibited a good proof of that conclusion.

From the study it can be possible to administer each of the Tasks (i.e. Tasks A_1, Tasks A_2, Tasks A_3, Task B_1, Task B_2 and Tasks B_3) separately for assessment purposes; or they can be put together in two or administer them as done by the researcher in this study. The above assertion was made because the tasks, was independent of one another and complete as instruments of assessment hence the low correlation values obtained.

By considering the research findings within the assessment for science process skills proficiency, it is clear that only a few of the participating students were taken through weekly consistent elective physics practical work by their schools. Again it is clear that only a few of the participating sample exhibited some comparable levels of proficiency across all the skills of planning, performing and reasoning for both Tasks A and Tasks B. The findings of this study extend to earlier research as reported by Ampiah (2004) in the same Ghanaian senior high level in all the general science programme of elective: physics, biology and chemistry, which revealed that science teachers normally do not take general science programme students in SHS form 1 and 2 through(physics in this case/study) practical work until when they are close to taking the WASSCE, usually in form 3, since West Africa Examinations Council, will require some minimum number of practical to be conducted for the students before they undergo the WASSCE finally.

Some trends were observed and below are the possible reasons for such patterns:

I. Specific

1. The lowest proficiency in the science process skills in the study for Tasks A was performing skills. Below is the possible reason:

Teachers/Schools do more theory work than practical work, especially at the lower levels (i.e., forms 1 and 2 of the SHS).

2. In most of the tasks both in Tasks A and Tasks B girls schools performed better than boy schools and mixed schools had the lowest proficiencies in almost all the tasks carried out. Below are possible reasons that showed up in the study: The caliber of students admitted into the girl schools- bright. Female elective physics students seemed to attach more seriousness to the practical work compared to boys.

Some general factors to consider

General factors that accounted for the trend in results across the entire study include the following:

- i. Staff training and re-training, qualification, experience and exposure;
- ii. Staff motivation/stability;
- iii. School's teaching and learning strategies;
- iv. Quality of students in the elective physics classes;
- v. Recreational facilities for students and staff;
- vi. Learning habits and attitude of students in elective physics classes;

Implications of the Study

The implications of the study can be classified under four sections: for Schools and hence Science Teaching; Physics/Science Teachers; Elective Physics Students; and the Tasks (or Instruments):

Science Teachings

The results indicate that there are some areas in which there appears to be a mismatch between students' performance and the expected implication of the science curriculum materials, like the elective physics syllabus. The expectation is higher than actual performance demonstrated in the study. Teachers may wish to consider whether the performance of the individual students in their care might be improve by focusing their attention on the aspects that arise in the normal course of teaching. This would allow difficulties to become apparent at an early stage so that they could be dealt with promptly and systematically.

Schools

In the study some of the respondents indicated that they did not do any practical work from the responses required by the opinionnaire answered. This means school Heads need to challenge physics teachers to integrate their teaching using both the theory and the practical work alongside. From the study, it became obvious that some schools do not attach importance to the development of science process skills of the students at the lower forms (1 and 2). The school Heads should be advised on how best to create more periods reserved for practical work in physics and the other science subjects like, biology and chemistry. At least a minimum of two hours each week/every other week will be an appropriate beginning point.

Teachers

Science/elective physics teachers must be taken through training sessions/workshops in how to organize performing-based assessment procedures to enable them function effectively in their roles as facilitators. Physics teachers need to monitor effectively the practical/laboratory activities of students under them, in order to develop high levels of proficiency in science process skills, especially of planning, performing and reasoning among other skills. Physics teachers need to motivate and support students to develop high proficiencies in the course of the studies. Again teachers need to organize interesting as well as challenging performance-based assessments for students in elective physics at the senior high schools to keep their interest in science and in particular elective physics very high.

Students

Students in elective physics should be motivated to develop high proficiencies in laboratory activities, using both hands-on and mind-on skills of planning, performing and reasoning. Elective physics students should be taught the importance of accuracy and precision in measurement because of their fundamental usefulness. Again students should be discouraged from recording approximate values during data collection.

Tasks

This research work brings out the fact that short, separate, and independent performance tasks (Table 32 and Table 33) on individual concepts in physics can be used to assess laboratory skills of planning, performing and reasoning (Ossei-Anto, 1996). With the right training given to the teachers, similar tasks can be developed in physics and other branches of science for effective assessment of science process skills/laboratory skills of students in the entire general science programme at the SHS level.

Conclusions

This study has tested the research hypotheses and answered a research questions set out to investigate by the researcher. It has shown that in Cape Coast Metropolis of the Central Region of Ghana, elective physics students involved in laboratory work in general showed low proficiencies in science process skills of planning and performing. On the other hand, reasoning skills was the best in the concepts of reflection and refraction in optics.

The study has shown that female elective physics students obtained the highest level of proficiency in science process skills across all the tasks compared to the boys. Again, it has also established that girls only schools obtained the highest level of proficiency across all the tasks, followed by boys only schools, with mixed schools being the least proficient.

Overall, participation in the experiential activities-performance based assisted students in their ability to plan, perform and reason. By improving these science process skills, students may become better consumers of scientific knowledge in the future. They possibly will become better able to plan, perform ad reason and hence make educated conclusions based on their observations and judgement.

This study has added to the ever increasing support that performance assessment tasks are distinct, unique and able to measure the proficiency levels of science process skills when administered properly.

Recommendations

1. Head of Schools/Heads of Science Departments should see to it that physics practical work becomes part and parcel of the teaching and learning of elective physics each week.
2. Elective physics teachers should be trained by the researcher in the use of performance-based assessments.
3. Students in elective physics should be motivated by the physics teacher to develop high proficiencies in laboratory activities, using hands-on and minds-on skills of planning, performing and reasoning.
4. Similar tasks should be developed in elective physics in other branches such as heat, waves, and mechanics.

Suggestions for Further Research

This research provides many avenues for further study, below are few suggested topics.

i. The instrument used in this study must be used on larger sample size of senior high school students in other Regions of Ghana.

ii. A collaborative international study could be carried out across West African States involved in the WASSCE (e.g. in Liberia, Nigeria or Sierra-Leone).

iii. Tasks on performance-based assessment similar to the one used in this study should be designed and developed at various levels of our educational system (Junior High Schools, Colleges of Education and Universities).

iv. It will also be good to do further studies to find out whether the trend of findings were unique to Cape Coast Metropolis or is different in other, Districts, Municipals as well as Metropolis (i.e. in terms of gender as well as school type).

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APPENDICES

APPENDIX A

DEPARTMENT OF SCIENCE AND MATHEMATICS EDUCATION

E-mail: dsme@ucc.edu.gh
dsme@gmail.com
TELEGRAMS & CABLES:
UNIVERSITY, CAPE COAST
TELEPHONE:
OFFICE: 03321-34890

FACULTY OF EDUCATION
UNIVERSITY OF CAPE COAST
CAPE COAST, GHANA

Your Ref.:

Our Ref.: DSME/M.3/V.1/13

Date: 7th March, 2014

The Head
Holy Child School
Cape Coast

Dear Sir,

RESEARCH VISIT

The bearer of this letter, Mr. Eugene A. Johnson is a Ph.D (Science Education) student of the Department of Science and Mathematics Education, University of Cape Coast.

As part of the requirements for the award of a doctorate degree, he is required to undertake a research visit to your school which will require the participation of staff/students.

I would be very grateful if you could give him the necessary assistance he may need.

Thank you.

Dr. Eric M. Wilmot
HEAD

APENDIX B

TASKS A REFRACTION OF LIGHT

(TASK A1)

DESIGN AN EXPERIMENT

INTRODUCTION

This practical test offers a problem. You have 15 minutes to plan and come out with an experiment to solve the problem. You will be given additional 15 minutes to read the entire task before you start work.

PROBLEM:

Optometrists use the convex tens in spectacles of their patients. One type of test used to determine their focal length, f, is to use it to converge (gather/collect) an incident parallel narrow beam of light (from a distant object) to a point, known as the focal point. The length, f, is equal to the distance between the convex lens and the focal point.

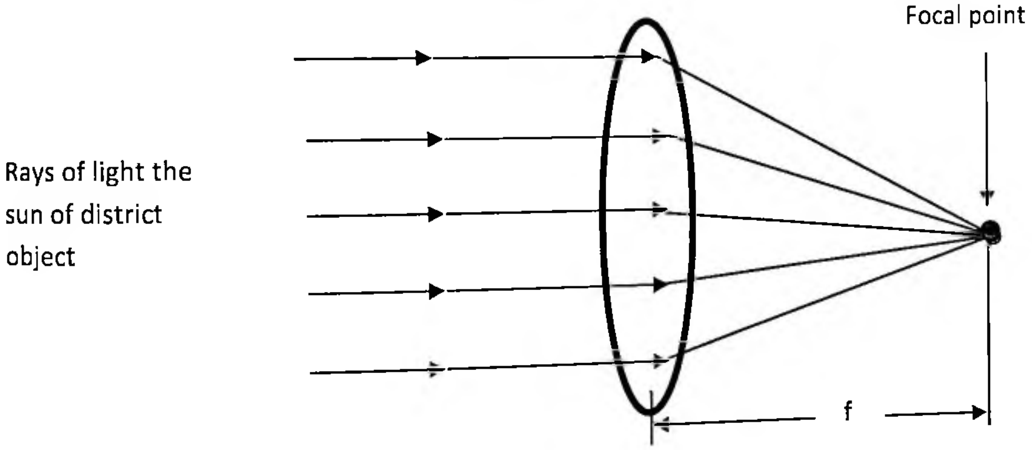

Fig.1. Converging lens showing the focal point and focal length

Assuming that you are doing an attachment during the holidays with Prima Optical Company and your role is to make sure you check critically that the lenses being sent to Ama, Efua, and Kofi are not mixed up. (Ama has a focal length of 15cm; Efua's is 20cm and Kofi's is 25cm);

(a) Under the heading PROCEDURE, list in order, the steps you will use to solve the problem. You may include diagram(s) to help illustrate your plans for the experiment. Include any safety procedures you would follow.

(b) At the end of the 15 minutes, you will be asked to stop work.

PLEASE NOTE: You are NOT to proceed with any part of the actual experiment. You are just to plan and organize a way to investigate the problem.

PROCEDURE

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DIAGRAMS

(TASK A2)

MEASURING AND COLLECTING DATA

INTRODUCTION

You are expected to use 15 minutes to do this work. Provision is made for all the materials you will need. Carefully record your work on the sheet provided. You will be given additional 5 minutes to read the entire task before you commence work.

EXAMPLE

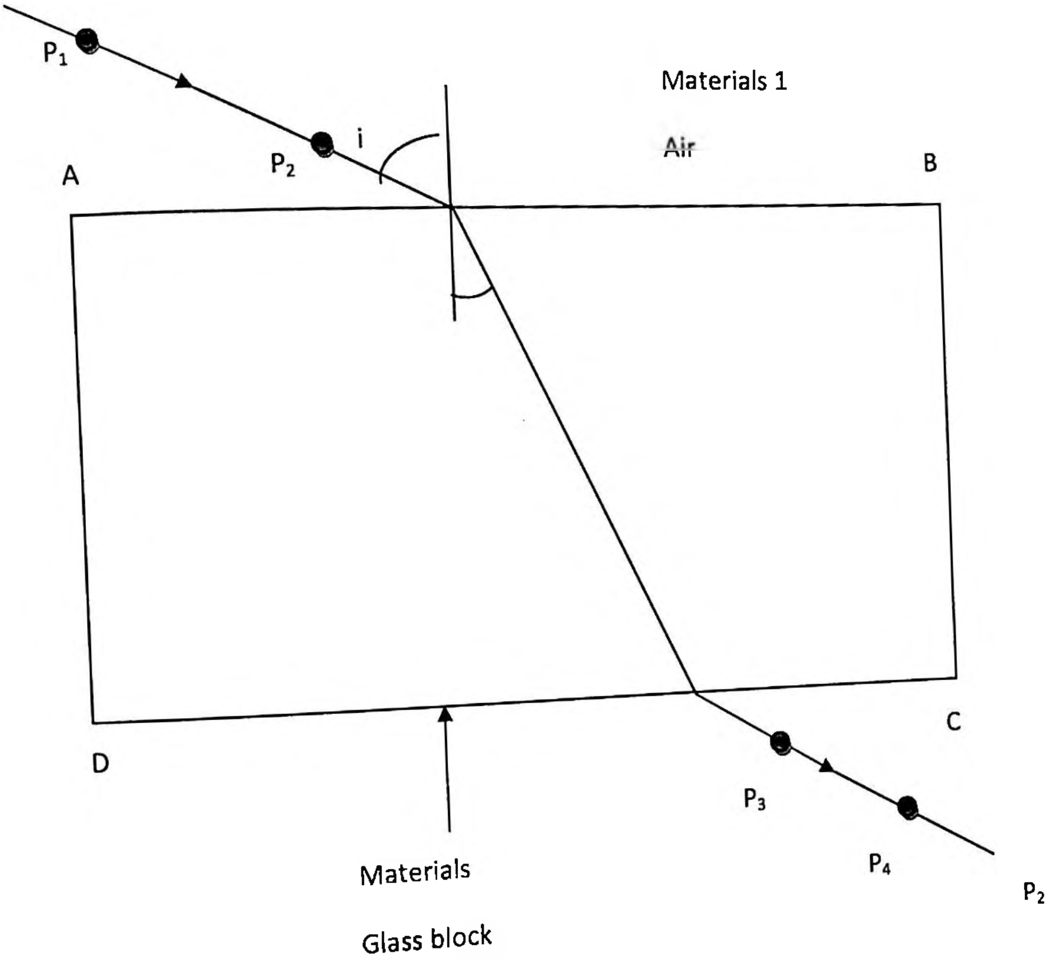


Fig.2. Light ray passing through a glass block from air.

PROBLEM:

You are to trace the path of a ray of light as it travels from material 1 through material 2. You are also to measure the angle of incidence, i, and the corresponding angle of refraction, r.

MATERIALS:

Class block, Optical pins, Table of sine functions, 2-diagrams of rays of light from air to glass-block, ruler (30cm), Drawing board/Cardboard, Protractor, Clips for holding sheets with ray diagrams.

PROCEDURE:

(a) Place the diagram labeled sheet No 1 on the drawing board and clip it. Then place the glass block on the sheet as shown (see (EXAMPLE).

(b) Put pins P1 and P2 on the incident ray, AO.

(c) Locate the images of pins P1 and P2 from the block by looking through the glass block from the opposite side.

(d) Position pin P3 and P4 so that they are in a STRAIGHT line with the images of P1 and P2.

(e) Join the point O, P3 and P4.

(f) Measure and record the values of the angle of incidence, i_A, and the angle of refraction, r_A.

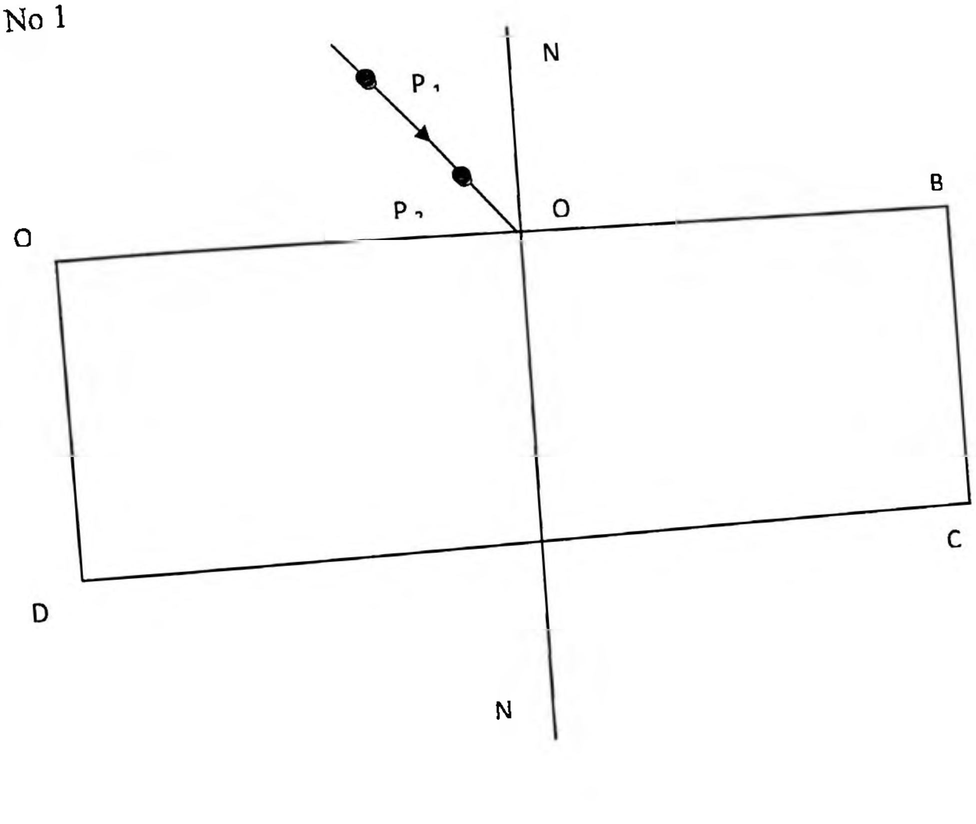
(g) Repeat steps (a) to (f) for the other incident ray BO (sheet labeled No 2) to obtain the corresponding values of angle i_B and r_B.

(h) At the end of the 15 minutes, you will be asked to stop work.

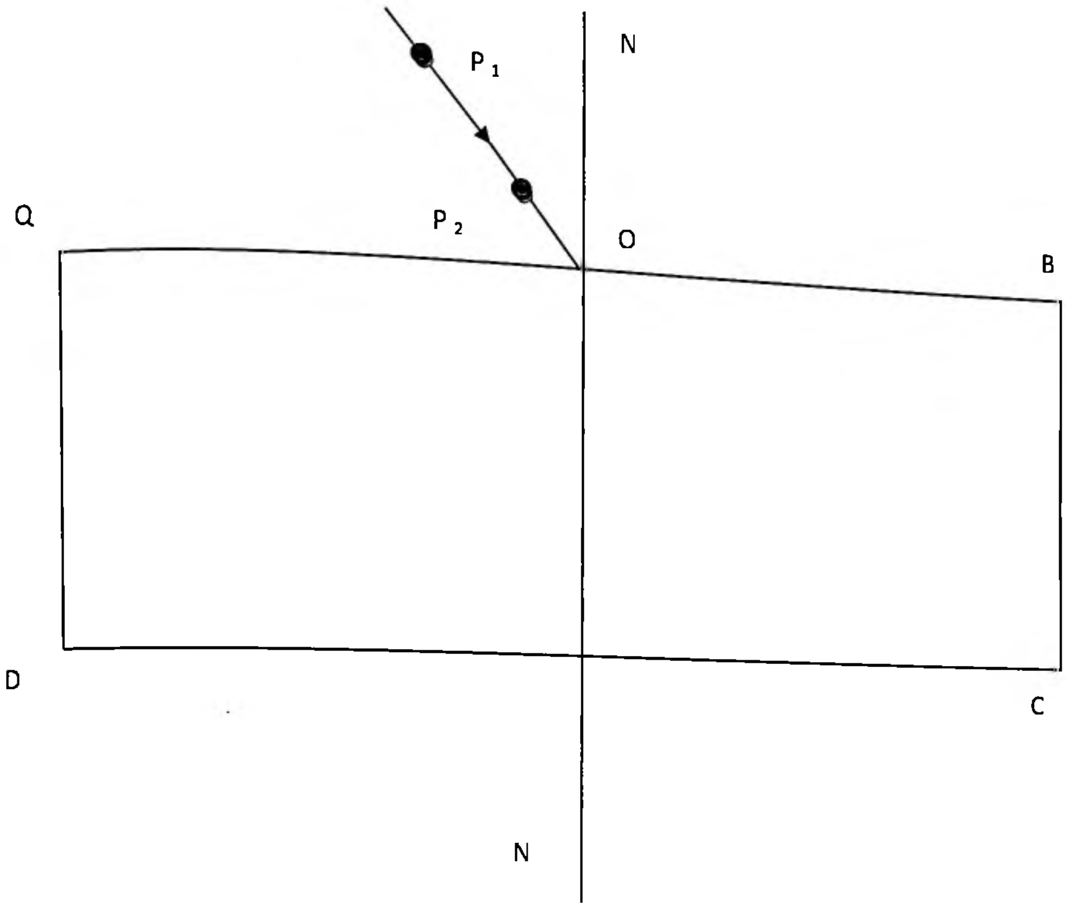
DATA TABLE

Angle of incidence (i) (degree)	Angle of refraction (r) (degree)	Sin i	Sin r
$i_A=$	$r_A=$		
$i_B =$	$r_B =$		

Sheet No 1

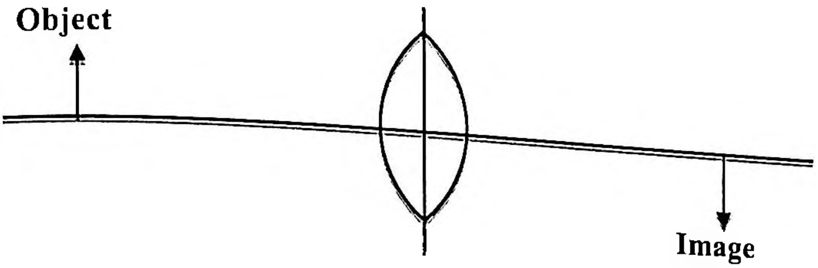


Sheet No 2

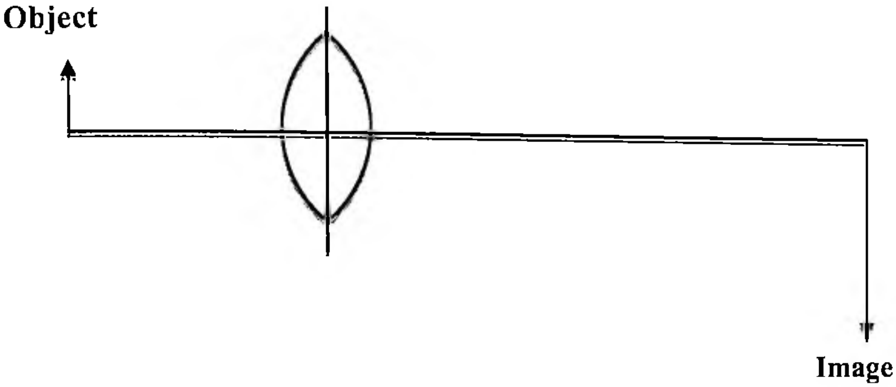


DIAGRAMS:

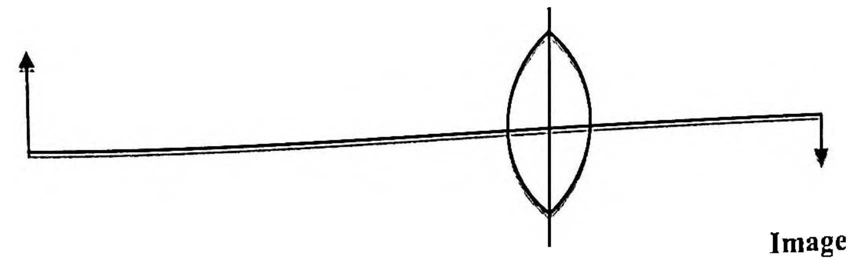
1.



2.



3.



PROCEDURE:

a) For each diagram, determine and record the value of the object distance, u and the corresponding value of the image distance, v, from the convex lens.

b) Determine the focal length, f, of the lens from the data. You are free to use the calculations or graphical methods to do it.

c) Indicate at the conclusion stage, the value you found for the focal length, f, of the lens.

d) State if any, sources of error that came into play during the task.

e) At the end of 15 minutes, you will be asked to stop work.

DATA TABLE

Object Distance (u) (cm)	Image Distance(v)(cm)	1/u	1/v	1/f	f

CALCULATIONS/GRAPH(S):

CONCLUSIONS:

SOURCES OF ERROR:

SAFETY PRECAUTIONS:

STUDENT OPINIONNAIRE

This section contains your reaction to the assessment task you have just completed.

1. Task A1

Planning

(a) Time provided : Not enough ....

About right ....

Too much ....

(b) Difficulty of task: Easy ....

About right ....

Difficult ....

(c) Any other comments: ....

2. Task A2

Performing

(a) Time provided : Not enough ....

About right ....

Too much ....

(b) Difficulty of task: Easy ....

About right ....

Difficult ....

(c) Any other comments: ....

....

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3. Task A3

Reasoning

(a) Time provided : Not enough ………………………………

About right ………………………………

Too much ………………………………

(b) Difficulty of task: Easy ………………………………

About right ………………………………

Difficult ………………………………

(c) Any other comments: ………………………………

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4. How would you commend revising tasks to make them better?

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APPENDIX C

TASKS B REFLECTION OF LIGHT

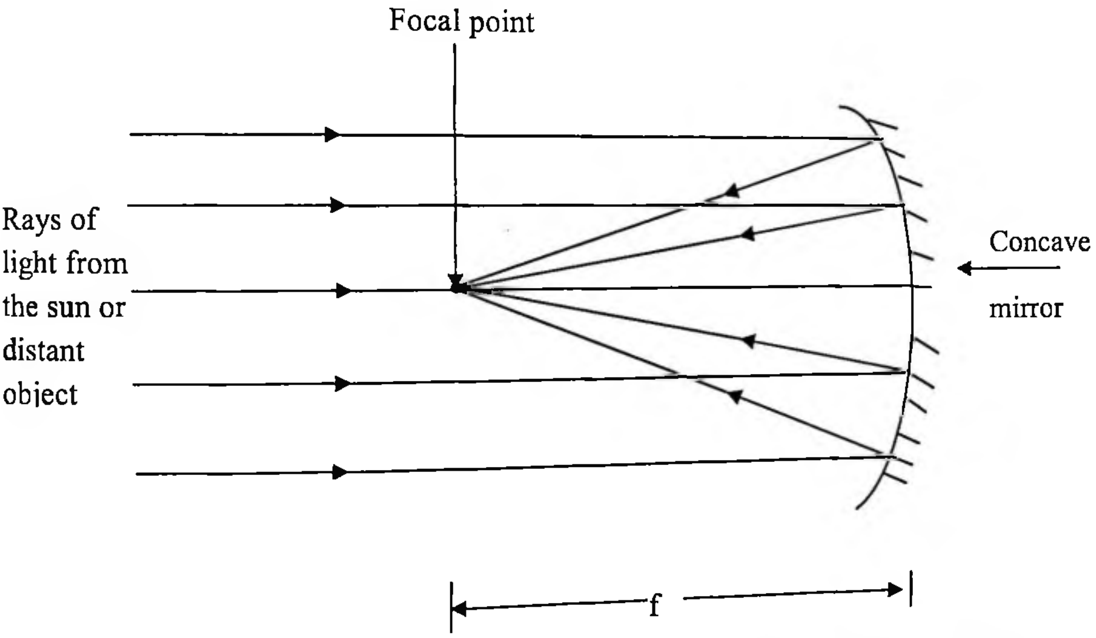
TASK B1

Introduction

This laboratory/practical test gives a problem. You will be given 15 minutes to design an experiment to solve the problem. You will be given 5 minutes to read through the entire task before starting.

Problem:

A test physicists use to determine the focal length, f, of a concave mirror is to be used to converge at an incident parallel narrow beam of light (from a distant object) to a point called the focal point.



Assuming that you are doing vacation job with Aboso Optical Mirror Manufacturing Company and your major assignment is to check that the right concave mirrors are sent out without mixing them up. Three SHS institutions; school A, School B, and School C have placed orders.

School A has focal length, 10cm; schools B, focal length, 20 cm and school C focal length, 30cm.

(a) Under the heading PROCEDURE, list in order, the steps you will use to solve the problem. You may include diagram(s) to illustrate your plan for the experiment. Safety precautions may be included.

(b) At the end of 15 minutes, you will be asked to stop work.

PLEASE NOTE: This does not require any actual practical work/experiment. You are just to plan and organize an approach to investigate the problem.

PROCEDURE

DIAGRAM (S)

Safety Precautions

REFLECTION OF LIGHT

TASK (B2)

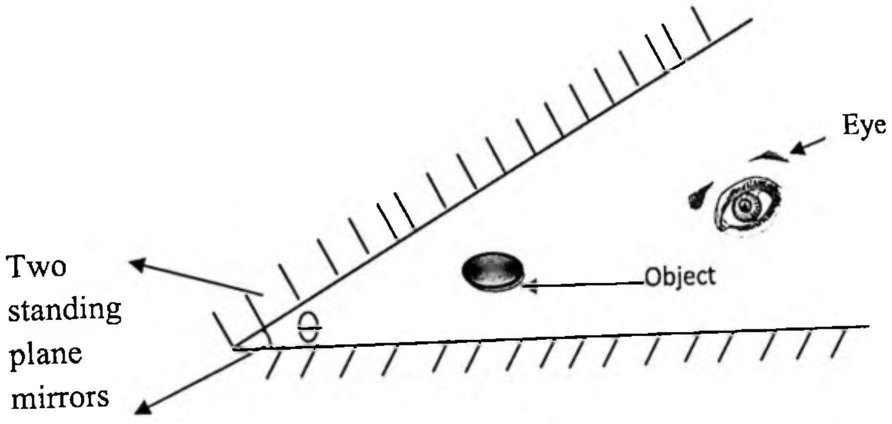
Introduction

You will have 15 minutes to complete this part. You have been given a list of materials. Record your work on the answer sheet under the appropriate headings. Additional 5 minutes will be given to you to read the entire task before starting.

Problem:

You should make careful observations of image of an object put between two plane mirrors. You are again to count the total number of images, n, as seen with the two plane mirrors.

Example



The diagram is made up of two standing plane mirrors inclined at an angle Θ, to each other; with an object placed close to and between them.

MATERIALS

- Protractor
- Ruler (30cm)
- Two plane mirrors.
- Pencil
- Object

- Two mirror holders

PROCEDURE

(a) Incline the two plane mirrors at an angle of 120° to each other.

(b) Place the object, O, between the two plane mirrors, as shown (see example).

(c) Position yourself so that you can see all the images of the object in the two mirrors simultaneously.

(d) Count and record (in the Data Table) the TOTAL number of images, n, of the object, O, as seen in the two mirrors.

(e) Repeat steps (a) to (d) with the two plane mirrors inclined at an angle of 90°; then at 72°; and then 60°.

(f) Under the heading DESCRIPTION

  I. Describe how the images appear compared to the object

  II. Describe any pattern, or trend, of the number of images, n, compared to the angle Θ, between the two plane mirrors.

(g) At the end of 15 minutes, you will be asked to stop work.

DATA TABLE

Angle between two inclined standing plane mirrors (Θ) (degrees)	Total number of images seen in both plane mirrors (n)
120°	
90°	
72°	
60°	

DESCRIPTION (A)

DESCRIPTION (B)

DIAGRAM

TASK (B3)

Introduction:

You will be given 15 minutes to complete this part. Record your work on the answer sheet under the various headings. You will be given additional 5 minutes to read the entire task before starting.

Problem:

You are to determine the focal length f, of a concave mirror through the mirror formula:

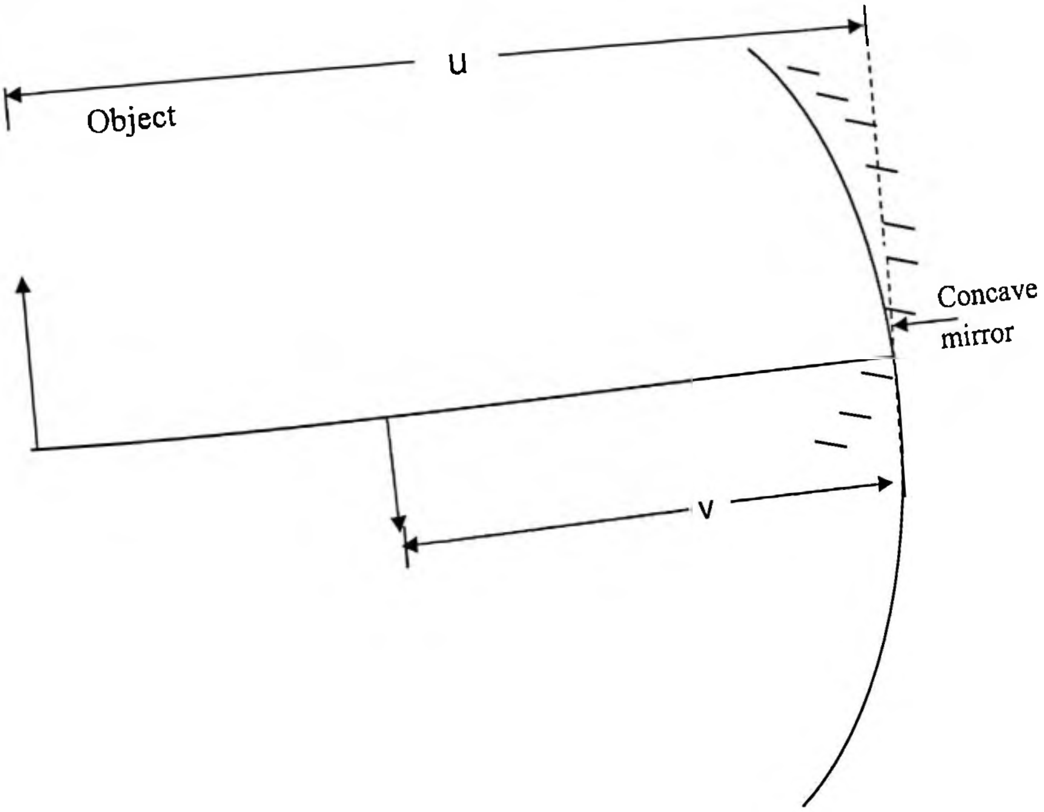
$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

Where

u = distance from object to mirror

v = distance from image to mirror

f = focal length of the mirror

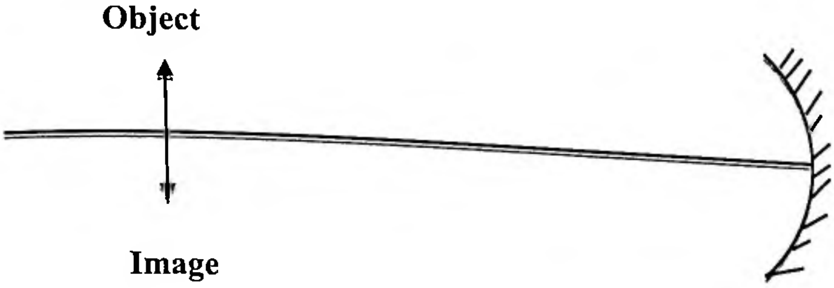


MATERIALS

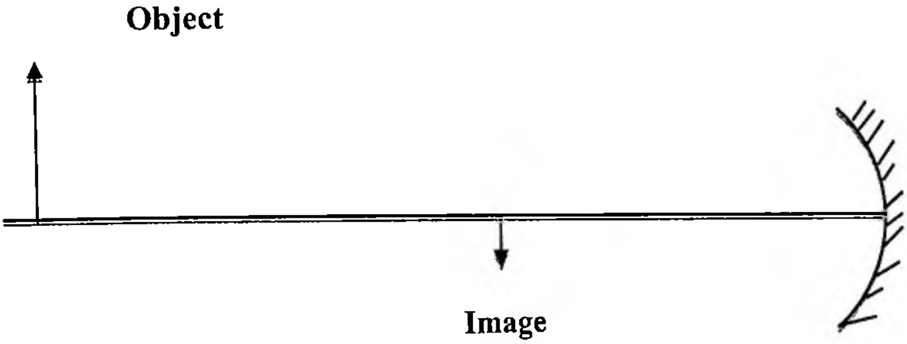
- Ruler (30cm) Calculator A sheet of 3 diagrams

DIAGRAMS

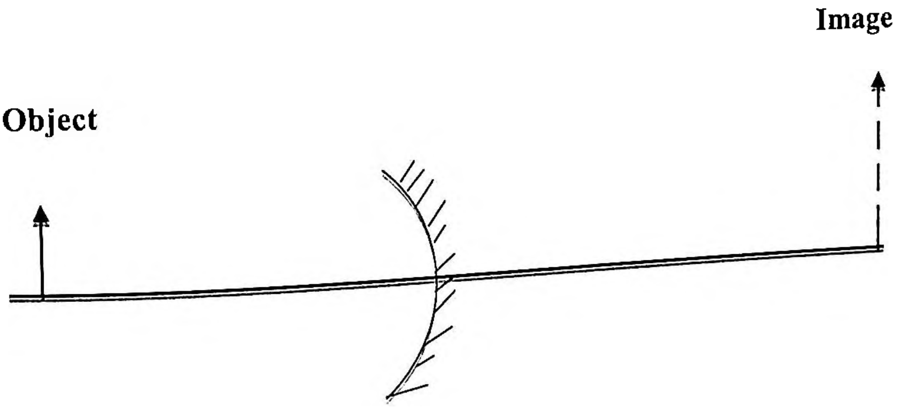
1.



2.



3.



PROCEDURE

(a) For each diagram (see sheet of diagram), measure and record the value of the object distance, u, and the corresponding value of image distance, v. Record these values in the Data Table provided.

(b) Determine the focal length, f, of the mirror you may use calculations or graphs to do this.

(c) Under the heading conclusion report the value you determined for the focal length, f, of the mirror.

(d) Cite any errors that were involved with the determination.

(e) At the end of the 15 minutes you will be asked to stop work.

Object Distance (u) (cm)	Image Distance (v) (cm)	$\frac{1}{U}$	$\frac{1}{v}$	$\frac{1}{f}$	f

Calculations / Graph(s)

CONCLUSION

STUDENT OPINIONNAIRE

This section contains your reaction to the assessment task you have just completed.

1. Task B1

Planning

(a) Time provided : Not enough ....

About right ....

Too much ....

(b) Difficulty of task: Easy ....

About right ....

Difficult ....

(c) Any other comments: ....

2. Task B2

Performing

(a) Time provided : Not enough ....

About right ....

Too much ....

(b) Difficulty of task: Easy ....

About right ....

Difficult ....

(c) Any other comments: ....

....

3. Task B3

Reasoning

(a) Time provided : Not enough ....

About right ....

Too much ....

(b) Difficulty of task: Easy ....

About right ....

Difficult ....

(c) Any other comments: ....

....

....

4. How would you commend revising this tasks to make them better?

....

....

....

APPENDIX D

SCORING FORMAT AND DETAILED MARKING SCHEME

Key to the Detailed Marking Scheme

III. No credit can mean the following

v. No response

vi. Inappropriate response (wrong answer)

vii. No response and inappropriate response

viii. The above equals = No credit = (0)

ix. Appropriate response (correct answer) = full credit = 1.

Task A

0 = No Credit, 1 = Full Credit

Planning

1.	General Strategy	0	1
2.	Sequenced Plan	0	1
3.	Detail Plan	0	1
4.	Feasible /Workable Plan	0	1
5.	Appropriate Diagram	0	1
6.	Safety Procedures	0	1

Scoring Details

Task A (Refraction of Light)

Tasks A1: Planning 0 1

1. General Strategy

Score 1 if student shows/demonstrates any kind of planning.

2. Sequenced Plan	0	1
Score 1 if student's plan is sequenced in a logical manner.		
3. Detailed Plan	0	1
Score 1 if student's plan is very detailed		
4. Feasible/Workable Plan	0	1
5. Appropriate Diagram	0	1
6. Safety Procedures	0	1

Task A: Scoring Format

Performing

Accurate value of i_A	0	1
Accurate value of r_A	0	1
$r_A < i_A$	0	1
Accurate value of i_B	0	1
Accurate value of r_B	0	1
$r_B < i_B$	0	1

Sine Functions of Angles

Correct estimations (at least two are correct)	0	1
OR		
Correct axes	0	1
Points plotted correctly	0	1

Conclusion

Value of “f” between (2.20cm-2.40cm)

0 1

Sources of Error

0 1

Scoring Details

Task A2: Performing

1. Accurate value of i_A

0 1

Score 1 if student’s value is 29° between 31°.

2. Accurate value of r_A

0 1

Score 1 if student’s value is between 18° and 20°.

Score 0 if there is no evidence of tracking/tracing of refracted angle.

3. Score 1 if value of student’s measurement is correct from his/her sheet (Give 1° error only)

Score 0 if there is no evidence of tracking/tracing if refracted angle.

4. Accurate value of i_B 0 1

Score 1 if student’s value is between 49° and 51°.

5. Accurate value of r_B is between 29° and 31°. 0 1

Score 0 if there is no evidence of tracking/tracing of refracted angle.

Score 1 if value of student’s measurement is correct from his/her sheet (Give 1° error only).

Score 0 if there is no evidence of tracking/tracing of refracted angle.

0 1

Correct estimations/computation

6. Score 1 if at least two of the sine functions are correct. 0 1

0 1

7. Value of “f” between

0 1

8. Sources of Error

Scoring Format

Task A3: Reasoning

One or two are accurate		
Additional one/two are accurate	0	1
(i.e. ¾ accurate overall)		1
Additional one/two are accurate (i.e. 5/6 are accurate overall)	0	1
Reciprocal calculations (columns $\frac{i}{u}$ *and* $\frac{i}{v}$ at least three are correct	0	1
Calculations/Graph		
Using either:		
Adding reciprocals $\frac{i}{u}+\frac{i}{v}$ either	0	1
Computing “f’ from $\frac{i}{f}$	0	1
Correct axes	0	1
Points plotted correctly	0	1
Conclusion		
Value of “f’ as;	0	1
Sources of Error	0	1

Scoring Details Task A3

Reasoning

Measurements/Observations (Max = 3 marks)

Specified unite of measurement from Data Table are cm only.

Object distance are; 4.5cm; 3.0cm; 5.5cm

Corresponding image distances are: 4.7cm; 8.4cm; 3.9cm (permit error of 0.1cm in each situation)

Reciprocal Calculations

(columns $\frac{i}{u}$ *and* $\frac{i}{v}$

0 1

Score 1 if at least three are correct (from the values in columns 1 and 2).

(Allow uncalculated fractions as well)

Calculations/Graph (Max = 2 marks either

Score 1 if student shows "addition" of one set of reciprocals.

Score 1 if student computers one value /values of "f" (don't punish students for wrong value of "f")

OR

Score 1 if student's graph has correct axes ($\frac{i}{u}$ *and* $\frac{i}{v}$).

Score 1 if student plots at least two of the three points correctly.

Conclusion

- Score 1 if student's value of "f" is between 2.4cm and 2.6cm 0 1
- Score 1 for any appropriate source/sources of error. 0 1

Task B

Planning

1. General Strategy 0 1
2. Sequenced Plan 0 1
3. Detail Plan 0 1
4. Feasible /Workable Plan 0 1
5. Appropriate Diagram 0 1

6. Safety Procedures

0 1

Scoring Details

Task A (Reflection of Light)

Tasks B1: Planning

1. General Strategy 0 1

   Score 1 if student shows/demonstrates any kind of planning.

2. Sequenced Plan 0 1

   Score 1 if student's plan is sequenced in a logical manner.

3. Detailed Plan 0 1

   Score 1 if student's plan is very detailed

4. Feasible/Workable 0 1

   Score 1 if student's plan is very workable

5. Appropriate Diagram 0 1

   Score 1 for diagram/diagrams

6. Safety Procedures 0 1

   Score 1 for any appropriate safety procedure/procedures mentioned.

Task B: Scoring Format

Scoring Format Performing

1. Accurate value of total number of images seen with mirrors at 120° inclination 0 1

2. Accurate value of total number of images seen with mirrors at 90° inclination 0 1
3. Accurate value of total number of images seen with mirrors at 72° inclination 0 1
4. Accurate value of total number of images seen with mirrors at 60° inclination 0 1

- Correct appearance of images compared to the object. 0 1

Correct pattern or trend of the number of images, n, compared to the angle θ, between the two plane mirrors.

Appropriate Diagram 0 1

Appropriate safety procedure 0 1

Scoring Details

Task B2

Performing

1. Score 1 for accurate value of images, n seen with mirrors at 120° inclination.
2. Score 1 for accurate value of the total number of images, n, seen with mirrors at 90° inclination.
3. Score 1 for accurate value of the total number of images, n, seen with mirrors at 72° inclination.
4. Score 1 for accurate value of total number, n seen with mirrors of 60° inclination.
5. Score max of 3for correct appearance of images compared to the object in the inclined mirrors.

6. Score 1 for correct pattern or trend of the number of images, n, compared to the angle, θ, between the two inclined mirrors.
7. Score 1 for any appropriate safety procedure stated.

Expected Results for Performing Task B2

A.

Angle, θ of inclination	Total no. of images seen
120°	2
90°	3
72°	4
60°	5

B. The images are virtual, erect, same size and same distance from image as with the object as well images more than one.

Task B3

Reasoning

Scoring Format

1. Accurate values of object distances, U, measured.	0	1
2. Accurate values of image distances, V measured	0	1
1. Accurate value of $\frac{1}{u}$ written.	0	1
2. Accurate value of $\frac{1}{v}$ written.	0	1
3. Accurate value of $\frac{1}{u}$ correctly calculated	0	1
4. Accurate value of $\frac{1}{v}$ correctly calculated	0	1

5. Accurate value of $\frac{1}{f}$ written/estimated 0 1

OR

Using Graph

Correct axes of graph stated. 0 1

Correct plot of $\frac{1}{u}$ to scale 0 1

Accurate estimation of $\frac{1}{f}$ or from the graph 0 1

Any appropriate conclusion 0 1

Task B3

Reasoning

Scoring Details

- Score 1 for at least two values of U correctly measured.
- Score 1 for at least two values of v correctly measured.
- Score 1 for accurate values of at least two of the $\frac{1}{u}$ written correctly in the column.
- Score 1 for accurate values of at least two of the $\frac{1}{v}$ written correctly in the column.
- Score 1 for accurate values of at least two values of $\frac{1}{u}$ correctly estimated/calculated.
- Score 1 for accurate values of at least two values of $\frac{1}{v}$ correctly estimated/calculated.
- Score 1 for accurate value of $\frac{1}{f}$ written / estimated for at least two of the diagrams.

- Score 1 for accurate two values of ‘f’ between 2.4cm to 2.6cm calculated or estimated.
- Score 1 for any appropriate conclusion.

BR_1: Score for two u measured accurately.

BR_2: Score 1 for additional u measured accurately.

BR_3: Score 1 for two v measured accurately.

BR_4: Score 1 additional for v measured accurately.

BR_5: Score 1 for at least two values of $\frac{1}{u}$ or rightly written.

BR_6: Score 1 for at least two values of $\frac{1}{v}$rightly written calculated.

BR_7: Score for at least two values of “f’ rightly evaluated.

BR_8: Score 1 for at least two values of “f’ correctly determined.

BR_9: Score 1 for appropriate conclusion.

Between-Subjects Factors

		Value Label	N
Tasks	1	Refraction	141
	2	Reflection	114

Descriptive Statistics

	Tasks	Mean	Std. Deviation	N
PlanningTask	Refraction	.3901	.28856	141
	Reflection	.3670	.26900	114
	Total	.3797	.27968	255
PerformingTask	Refraction	.3394	.28343	141
	Reflection	.6140	.27602	114
	Total	.4622	.31127	255
ReasoningTask	Refraction	.6447	.27811	141
	Reflection	.5939	.21709	114
	Total	.6220	.25346	255

Box's M	9.530
F	1.568
df1	6
df2	4.125E5
Sig.	.152

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

a. Design: Intercept + Tasks

Multivariate Tests[c]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Intercept	Pillai's Trace	.890	6.799E2[a]	3.000	251.000	.000	.890	2039.843	1.000
	Wilks' Lambda	.110	6.799E2[a]	3.000	251.000	.000	.890	2039.843	1.000
	Hotelling's Trace	8.127	6.799E2[a]	3.000	251.000	.000	.890	2039.843	1.000
	Roy's Largest Root	8.127	6.799E2[a]	3.000	251.000	.000	.890	2039.843	1.000
Tasks	Pillai's Trace	.216	23.087[a]	3.000	251.000	.000	.216	69.261	1.000
	Wilks' Lambda	.784	23.087[a]	3.000	251.000	.000	.216	69.261	1.000
	Hotelling's Trace	.276	23.087[a]	3.000	251.000	.000	.216	69.261	1.000
	Roy's Largest Root	.276	23.087[a]	3.000	251.000	.000	.216	69.261	1.000

a. Exact statistic

b. Computed using alpha = .05

c. Design: Intercept + Tasks

Levene's Test of Equality of Error Variances[a]

	F	df1	df2	Sig.
PlanningTask	.350	1	253	.555
PerformingTask	1.493	1	253	.223
ReasoningTask	15.775	1	253	.000

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Tasks

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	PlanningTask	.034[a]	1	.034	.430	.513	.002	.430	.100
	PerformingTask	4.754[c]	1	4.754	60.574	.000	.193	60.574	1.000
	ReasoningTask	.163[d]	1	.163	2.550	.112	.010	2.550	.356
Intercept	PlanningTask	36.125	1	36.125	460.811	.000	.646	460.811	1.000
	PerformingTask	57.303	1	57.303	730.145	.000	.743	730.145	1.000
	ReasoningTask	96.695	1	96.695	1.514E3	.000	.857	1514.394	1.000
Tasks	PlanningTask	.034	1	.034	.430	.513	.002	.430	.100
	PerformingTask	4.754	1	4.754	60.574	.000	.193	60.574	1.000
	ReasoningTask	.163	1	.163	2.550	.112	.010	2.550	.356
Error	PlanningTask	19.834	253	.078					
	PerformingTask	19.856	253	.078					
	ReasoningTask	16.154	253	.064					
Total	PlanningTask	56.639	255						
	PerformingTask	79.082	255						
	ReasoningTask	114.960	255						
Corrected Total	PlanningTask	19.868	254						
	PerformingTask	24.610	254						
	ReasoningTask	16.317	254						

a. R Squared = .002 (Adjusted R Squared = -.002)

b. Computed using alpha = .05

c. R Squared = .193 (Adjusted R Squared = .190)

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	PlanningTask	.034[a]	1	.034	.430	.513	.002	.430	.100
	PerformingTask	4.754[c]	1	4.754	60.574	.000	.193	60.574	1.000
	ReasoningTask	.163[d]	1	.163	2.550	.112	.010	2.550	.356
Intercept	PlanningTask	36.125	1	36.125	460.811	.000	.646	460.811	1.000
	PerformingTask	57.303	1	57.303	730.145	.000	.743	730.145	1.000
	ReasoningTask	96.695	1	96.695	1.514E3	.000	.857	1514.394	1.000
Tasks	PlanningTask	.034	1	.034	.430	.513	.002	.430	.100
	PerformingTask	4.754	1	4.754	60.574	.000	.193	60.574	1.000
	ReasoningTask	.163	1	.163	2.550	.112	.010	2.550	.356
Error	PlanningTask	19.834	253	.078					
	PerformingTask	19.856	253	.078					
	ReasoningTask	16.154	253	.064					
Total	PlanningTask	56.639	255						
	PerformingTask	79.082	255						
	ReasoningTask	114.960	255						
Corrected Total	PlanningTask	19.868	254						
	PerformingTask	24.610	254						
	ReasoningTask	16.317	254						

a. R Squared = .002 (Adjusted R Squared = -.002)

b. Computed using alpha = .05

d. R Squared = .010 (Adjusted R Squared = .006)

Between-Subjects Factors

		Value Label	N
SexRefraction	1	Female	61
	2	Male	80

Descriptive Statistics

	SexRefraction	Mean	Std. Deviation	N
RefractionPlanning1	Female	.3880	.31139	61
	Male	.3917	.27186	80
	Total	.3901	.28856	141
RefractionPerforming1	Female	.3185	.27651	61
	Male	.3536	.28839	80
	Total	.3384	.28285	141
RefractionReasoning1	Female	.6623	.28353	61
	Male	.6275	.28013	80
	Total	.6426	.28113	141

Box's Test of Equality of Covariance Matrices[a]

Box's M	4.172
F	.679
df1	6
df2	1.160E5
Sig.	.667

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

a. Design: Intercept + SexRefraction

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Intercept	Pillai's Trace	.865	2.919E2[a]	3.000	137.000	.000	.865	875.616	1.000
	Wilks' Lambda	.135	2.919E2[a]	3.000	137.000	.000	.865	875.616	1.000
	Hotelling's Trace	6.391	2.919E2[a]	3.000	137.000	.000	.865	875.616	1.000
	Roy's Largest Root	6.391	2.919E2[a]	3.000	137.000	.000	.865	875.616	1.000
SexRefraction	Pillai's Trace	.009	.402[a]	3.000	137.000	.752	.009	1.207	.128
	Wilks' Lambda	.991	.402[a]	3.000	137.000	.752	.009	1.207	.128
	Hotelling's Trace	.009	.402[a]	3.000	137.000	.752	.009	1.207	.128
	Roy's Largest Root	.009	.402[a]	3.000	137.000	.752	.009	1.207	.128

a. Exact statistic

b. Computed using alpha = .05

Tests of Between-Subjects Effects

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power^b
Intercept	Pillai's Trace	.865	2.919E2^a	3.000	137.000	.000	.865	875.616	1.000
	Wilks' Lambda	.135	2.919E2^a	3.000	137.000	.000	.865	875.616	1.000
	Hotelling's Trace	6.391	2.919E2^a	3.000	137.000	.000	.865	875.616	1.000
	Roy's Largest Root	6.391	2.919E2^a	3.000	137.000	.000	.865	875.616	1.000
SexRefraction	Pillai's Trace	.009	.402^a	3.000	137.000	.752	.009	1.207	.128
	Wilks' Lambda	.991	.402^a	3.000	137.000	.752	.009	1.207	.128
	Hotelling's Trace	.009	.402^a	3.000	137.000	.752	.009	1.207	.128
	Roy's Largest Root	.009	.402^a	3.000	137.000	.752	.009	1.207	.128

a. Exact statistic

c. Design: Intercept + SexRefraction

Levene's Test of Equality of Error Variances^a

	F	df1	df2	Sig.
RefractionPlanning1	4.065	1	139	.046
RefractionPerforming1	.118	1	139	.732
RefractionReasoning1	.075	1	139	.784

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Sex Refraction

Source	Dependent Variable	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power^{b}
Corrected Model	RefractionPlanning1	.000^{a}	1	.000	.006	.940	.000	.006	.051
	RefractionPerforming1	.043^{c}	1	.043	.530	.468	.004	.530	.112
	RefractionReasoning1	.042^{d}	1	.042	.528	.469	.004	.528	.112
Intercept	RefractionPlanning1	21.038	1	21.038	250.860	.000	.643	250.860	1.000
	RefractionPerforming1	15.633	1	15.633	194.745	.000	.584	194.745	1.000
	RefractionReasoning1	57.576	1	57.576	726.049	.000	.839	726.049	1.000
SexRefraction	RefractionPlanning1	.000	1	.000	.006	.940	.000	.006	.051
	RefractionPerforming1	.043	1	.043	.530	.468	.004	.530	.112
	RefractionReasoning1	.042	1	.042	.528	.469	.004	.528	.112
Error	RefractionPlanning1	11.657	139	.084					
	RefractionPerforming1	11.158	139	.080					
	RefractionReasoning1	11.023	139	.079					
Total	RefractionPlanning1	33.111	141						
	RefractionPerforming1	27.347	141						
	RefractionReasoning1	69.280	141						

Corrected Total	RefractionPlanning1	11.657	140						
	RefractionPerforming1	11.200	140						
	RefractionReasoning1	11.065	140						

a. R Squared = .000 (Adjusted R Squared = -.007)
b. Computed using alpha = .05
c. R Squared = .004 (Adjusted R Squared = -.003)
d. R Squared = .004 (Adjusted R Squared = -.003)

Between-Subjects Factors

		Value Label	N
SexReflection	1	Female	57
	2	Male	57

Descriptive Statistics

	SexReflection	Mean	Std. Deviation	N
[illegible]	Female	.4004	.21281	57
	Male	.3219	.26151	57
	Total	.3619	[illegible]	114
[illegible]	Female	.5915	.29953	57
	Male	.6366	.25047	57
	Total	.6140	[illegible]	114
	Female	.5825	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]	[illegible]

Between-Subjects Factors

		Value Label	N
SexReflection	1	Female	57
	2	Male	57

Descriptive Statistics

	SexReflection	Mean	Std. Deviation	N
ReflectionPlanning1	Female	.4064	.27280	57
	Male	.3275	.26157	57
	Total	.3670	.26900	114
ReflectionPerforming1	Female	.5915	.29995	57
	Male	.6366	.25047	57
	Total	.6140	.27602	114
ReflectionReasoning1	Female	.5825	.21805	57
	Male	.6053	.21747	57
	Total	.5939	.21709	114

Box's Test of Equality of Covariance Matrices[a]

Box's M	2.741
F	.444
df1	6
df2	9.088E4
Sig.	.850

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

a. Design: Intercept + SexReflection

Multivariate Tests[c]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Intercept	Pillai's Trace	.916	4.012E2[a]	3.000	110.000	.000	.916	1203.667	1.000
	Wilks' Lambda	.084	4.012E2[a]	3.000	110.000	.000	.916	1203.667	1.000
	Hotelling's Trace	10.942	4.012E2[a]	3.000	110.000	.000	.916	1203.667	1.000
	Roy's Largest Root	10.942	4.012E2[a]	3.000	110.000	.000	.916	1203.667	1.000
SexReflection	Pillai's Trace	.046	1.764[a]	3.000	110.000	.158	.046	5.291	.449
	Wilks' Lambda	.954	1.764[a]	3.000	110.000	.158	.046	5.291	.449
	Hotelling's Trace	.048	1.764[a]	3.000	110.000	.158	.046	5.291	.449
	Roy's Largest Root	.048	1.764[a]	3.000	110.000	.158	.046	5.291	.449

a. Exact statistic

b. Computed using alpha = .05

c. Design: Intercept + SexReflection

Levene's Test of Equality of Error Variances[a]

	F	df1	df2	Sig.
ReflectionPlanning1	.573	1	112	.451
ReflectionPerforming1	5.967	1	112	.016
ReflectionReasoning1	.001	1	112	.972

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + SexReflection

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power^b
Corrected Model	ReflectionPlanning1	.178^a	1	.178	2.487	.118	.022	2.487	.346
	ReflectionPerforming1	.058^c	1	.058	.760	.385	.007	.760	.139
	ReflectionReasoning1	.015^d	1	.015	.313	.577	.003	.313	.086
Intercept	ReflectionPlanning1	15.351	1	15.351	214.942	.000	.657	214.942	1.000
	ReflectionPerforming1	42.982	1	42.982	562.954	.000	.834	562.954	1.000
	ReflectionReasoning1	40.204	1	40.204	847.860	.000	.883	847.860	1.000
SexReflection	ReflectionPlanning1	.178	1	.178	2.487	.118	.022	2.487	.346
	ReflectionPerforming1	.058	1	.058	.760	.385	.007	.760	.139
	ReflectionReasoning1	.015	1	.015	.313	.577	.003	.313	.086
Error	ReflectionPlanning1	7.999	112	.071					
	ReflectionPerforming1	8.551	112	.076					
	ReflectionReasoning1	5.311	112	.047					

Between-Subjects Factors

		Value Label	N
SchoolTypeRefraction	1	Boys only	40
	2	Girls only	59
	3	Mixed	42

Descriptive Statistics

	SchoolTypeRefraction	Mean	Std. Deviation	N
RefractionPlanning2	Boys only	.5167	.29671	40
	Girls only	.4463	.28271	59
	Mixed	.1905	.16285	42
	Total	.3901	.28856	141
RefractionPerforming2	Boys only	.3500	.28193	40
	Girls only	.3462	.27848	59
	Mixed	.3197	.29734	42
	Total	.3394	.28343	141
RefractionPReasoning2	Boys only	.7600	.22395	40
	Girls only	.6610	.25530	59
	Mixed	.5119	.30460	42
	Total	.6447	.27811	141

Box's Test of Equality of Covariance Matrices[a]

Box's M	24.876
F	2.005
df1	12
df2	7.353E4
Sig.	.020

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

a. Design: Intercept + SchoolTypeRefraction

Multivariate Tests[d]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Intercept	Pillai's Trace	.890	3.656E2[a]	3.000	136.000	.000	.890	1096.797	1.000
	Wilks' Lambda	.110	3.656E2[a]	3.000	136.000	.000	.890	1096.797	1.000
	Hotelling's Trace	8.065	3.656E2[a]	3.000	136.000	.000	.890	1096.797	1.000
	Roy's Largest Root	8.065	3.656E2[a]	3.000	136.000	.000	.890	1096.797	1.000
SchoolTypeRefraction	Pillai's Trace	.265	6.983	6.000	274.000	.000	.133	41.899	1.000
	Wilks' Lambda	.736	7.505[a]	6.000	272.000	.000	.142	45.029	1.000
	Hotelling's Trace	.357	8.024	6.000	270.000	.000	.151	48.147	1.000
	Roy's Largest Root	.351	16.045[c]	3.000	137.000	.000	.260	48.134	1.000

a. Exact statistic

b. Computed using alpha = .05

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

d. Design: Intercept + SchoolTypeRefraction

Levene's Test of Equality of Error Variances[a]

	F	df1	df2	Sig.
RefractionPlanning2	9.074	2	138	.000
RefractionPerforming2	.554	2	138	.576
RefractionPReasoning2	2.664	2	138	.073

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + SchoolTypeRefraction

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	RefractionPlanning2	2.501[a]	2	1.250	18.847	.000	.215	37.694	1.000
	RefractionPerforming2	.024[c]	2	.012	.145	.866	.002	.289	.072
	RefractionPReasoning2	1.288[d]	2	.644	9.316	.000	.119	18.632	.976
Intercept	RefractionPlanning2	20.233	1	20.233	304.946	.000	.688	304.946	1.000
	RefractionPerforming2	15.697	1	15.697	193.012	.000	.583	193.012	1.000
	RefractionPReasoning2	56.817	1	56.817	821.842	.000	.856	821.842	1.000
SchoolTypeRefraction	RefractionPlanning2	2.501	2	1.250	18.847	.000	.215	37.694	1.000
	RefractionPerforming2	.024	2	.012	.145	.866	.002	.289	.072
	RefractionPReasoning2	1.288	2	.644	9.316	.000	.119	18.632	.976
Error	RefractionPlanning2	9.156	138	.066					
	RefractionPerforming2	11.223	138	.081					
	RefractionPReasoning2	9.540	138	.069					

Total	RefractionPlanning2	33.111	141						
	RefractionPerforming2	27.490	141						
	RefractionPReasoning2	69.430	141						
Corrected Total	RefractionPlanning2	11.657	140						
	RefractionPerforming2	11.246	140						
	RefractionPReasoning2	10.829	140						

a. R Squared = .215 (Adjusted R Squared = .203)

b. Computed using alpha = .05

c. R Squared = .002 (Adjusted R Squared = -.012)

d. R Squared = .119 (Adjusted R Squared = .106)

Between-Subjects Factors

		Value Label	N
SchoolTypeReflection	1	BOYS ONLY	39
	2	GIRLS ONLY	38
	3	MIXED	37

Descriptive Statistics

	SchoolTypeReflection	Mean	Std. Deviation	N
ReflectionPlanning2	BOYS ONLY	.3376	.26070	39
	GIRLS ONLY	.5263	.23737	38
	MIXED	.2342	.22723	37
	Total	.3670	.26900	114
ReflectionPerforming2	BOYS ONLY	.6520	.23127	39
	GIRLS ONLY	.6654	.27444	38
	MIXED	.5212	.30345	37
	Total	.6140	.27602	114
ReflectionReasoning2	BOYS ONLY	.6051	.19460	39
	GIRLS ONLY	.6263	.22623	38
	MIXED	.5486	.22806	37
	Total	.5939	.21709	114

Box's Test of Equality of Covariance Matrices[a]

Box's M	16.298
F	1.305
df1	12
df2	5.946E4
Sig.	.207

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.

a. Design: Intercept + SchoolTypeReflection

Multivariate Tests[d]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Intercept	Pillai's Trace	.921	4.261E2[a]	3.000	109.000	.000	.921	1278.235	1.000
	Wilks' Lambda	.079	4.261E2[a]	3.000	109.000	.000	.921	1278.235	1.000
	Hotelling's Trace	11.727	4.261E2[a]	3.000	109.000	.000	.921	1278.235	1.000
	Roy's Largest Root	11.727	4.261E2[a]	3.000	109.000	.000	.921	1278.235	1.000
SchoolTypeReflection	Pillai's Trace	.230	4.755	6.000	220.000	.000	.115	28.527	.989
	Wilks' Lambda	.775	4.938[a]	6.000	218.000	.000	.120	29.627	.992
	Hotelling's Trace	.284	5.118	6.000	216.000	.000	.124	30.709	.993
	Roy's Largest Root	.262	9.595[c]	3.000	110.000	.000	.207	28.784	.997

a. Exact statistic

b. Computed using alpha = .05

c. The statistic is an upper bound on F that yields a lower bound on the significance level.

Multivariate Tests[d]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Intercept	Pillai's Trace	.921	4.261E2[a]	3.000	109.000	.000	.921	1278.235	1.000
	Wilks' Lambda	.079	4.261E2[a]	3.000	109.000	.000	.921	1278.235	1.000
	Hotelling's Trace	11.727	4.261E2[a]	3.000	109.000	.000	.921	1278.235	1.000
	Roy's Largest Root	11.727	4.261E2[a]	3.000	109.000	.000	.921	1278.235	1.000
SchoolTypeReflection	Pillai's Trace	.230	4.755	6.000	220.000	.000	.115	28.527	.989
	Wilks' Lambda	.775	4.938[a]	6.000	218.000	.000	.120	29.627	.992
	Hotelling's Trace	.284	5.118	6.000	216.000	.000	.124	30.709	.993
	Roy's Largest Root	.262	9.595[c]	3.000	110.000	.000	.207	28.784	.997

a. Exact statistic

b. Computed using alpha = .05

d. Design: Intercept + SchoolTypeReflection

Levene's Test of Equality of Error Variances[a]

	F	df1	df2	Sig.
ReflectionPlanning2	.389	2	111	.679
ReflectionPerforming2	3.164	2	111	.046
ReflectionReasoning2	.475	2	111	.623

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + SchoolTypeReflection

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[b]
Corrected Model	ReflectionPlanning2	1.650[a]	2	.825	14.035	.000	.202	28.070	.998
	ReflectionPerforming2	.475[c]	2	.238	3.242	.043	.055	6.485	.607
	ReflectionReasoning2	.121[d]	2	.060	1.286	.280	.023	2.572	.274
Intercept	ReflectionPlanning2	15.268	1	15.268	259.686	.000	.701	259.686	1.000
	ReflectionPerforming2	42.802	1	42.802	584.084	.000	.840	584.084	1.000
	ReflectionReasoning2	40.119	1	40.119	855.543	.000	.885	855.543	1.000
SchoolTypeReflection	ReflectionPlanning2	1.650	2	.825	14.035	.000	.202	28.070	.998
	ReflectionPerforming2	.475	2	.238	3.242	.043	.055	6.485	.607
	ReflectionReasoning2	.121	2	.060	1.286	.280	.023	2.572	.274
Error	ReflectionPlanning2	6.526	111	.059					
	ReflectionPerforming2	8.134	111	.073					

	ReflectionReasoning2	5.205	111	.047					
Total	ReflectionPlanning2	23.528	114						
	ReflectionPerforming2	51.592	114						
	ReflectionReasoning2	45.530	114						
Corrected Total	ReflectionPlanning2	8.177	113						
	ReflectionPerforming2	8.609	113						
	ReflectionReasoning2	5.326	113						

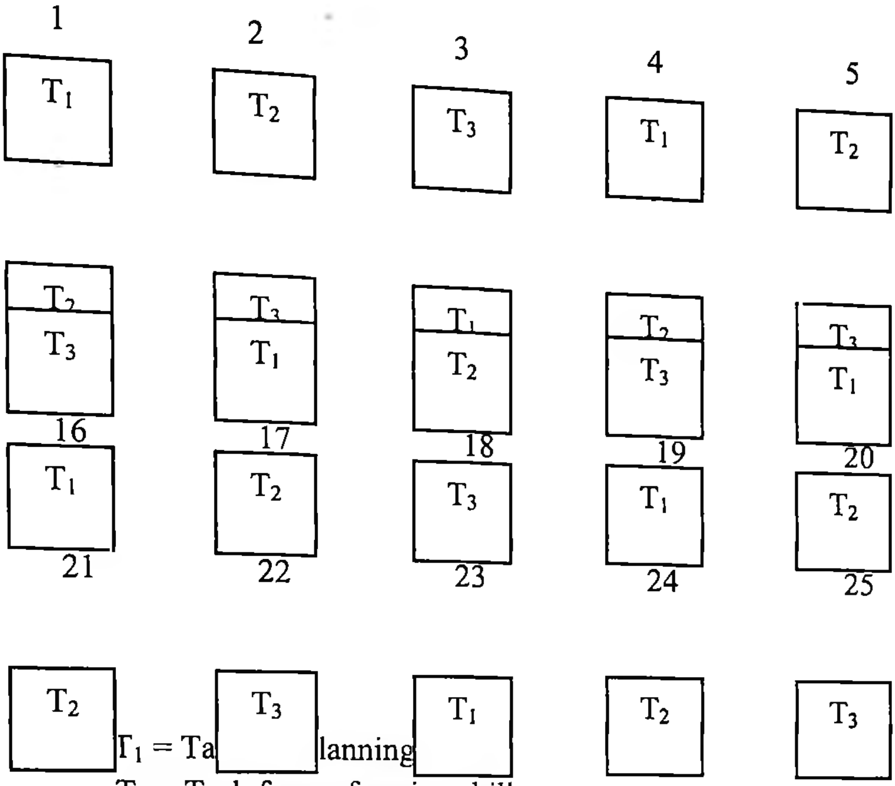
a. R Squared = .202 (Adjusted R Squared = .187)

b. Computed using alpha = .05

c. R Squared = .055 (Adjusted R Squared = .038)

d. R Squared = .023 (Adjusted R Squared = .005)

APPENDIX F
SEATING PLAN



T_1 = Ta lanning
T_2 = Task for performing skills
T_3 = Task for reasoning skills

APPEDIX G

SUMMARY OF SPSS OUTPUT FOR PILOT TESTING

PLANNING TASK A

Case Processing Summary

		N	%
Cases	Valid	33	100.0
	Excluded[a]	0	.0
	Total	33	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.789	6

PLANNING TASK B

Case Processing Summary

		N	%
Cases	Valid	29	87.9
	Excluded[a]	4	12.1
	Total	33	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.735	6

PERFORMING TASK A

Case Processing Summary

		N	%
Cases	Valid	33	100.0
	Excluded[a]	0	.0
	Total	33	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.907	7

PERFORMING TASK B

Case Processing Summary

		N	%
Cases	Valid	29	87.9
	Excluded[a]	4	12.1
	Total	33	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.849	8

REASONING TASK A

Case Processing Summary

		N	%
Cases	Valid	21	63.6
	Excluded[a]	12	36.4
	Total	33	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.846	8

REASONING TASK B

Case Processing Summary

		N	%
Cases	Valid	16	48.5
	Excluded[a]	17	51.5
	Total	33	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.820	9

RESULTS FOR ALL TASKS

(Planning Tasks A & B; Performing Task A & B; Reasoning Task A & B)

Case Processing Summary

		N	%
Cases	Valid	16	48.5
	Excluded[a]	17	51.5
	Total	33	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	N of Items
.844	44

APPENDIX H
SUMMARY OF SPSS OUTPUT FOR MAIN STUDY

PLANNING TASK A

Case Processing Summary

		N	%
Cases	Valid	141	55.3
	Excluded[a]	114	44.7
	Total	255	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.742	.748	6

PLANNING TASK B

Case Processing Summary

		N	%
Cases	Valid	114	44.7
	Excluded[a]	141	55.3
	Total	255	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.702	.701	6

PERFORMING TASK A

Case Processing Summary

		N	%
Cases	Valid	141	55.3
	Excluded[a]	114	44.7
	Total	255	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.774	.766	7

PERFORMING TASK B

Case Processing Summary

		N	%
Cases	Valid	114	44.7
	Excluded[a]	141	55.3
	Total	255	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.726	.729	7

REASONING TASK A

Case Processing Summary

		N	%
Cases	Valid	141	55.3
	Excluded[a]	114	44.7
	Total	255	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.829	.829	10

REASONING TASK B

Case Processing Summary

		N	%
Cases	Valid	114	44.7
	Excluded[a]	141	55.3
	Total	255	100.0

Case Processing Summary

		N	%
Cases	Valid	114	44.7
	Excluded[a]	141	55.3
	Total	255	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.753	.765	10

RESULTS FOR ALL TASKS

(Planning Tasks A & B; Performing Task A & B; Reasoning Task A & B)

Case Processing Summary

		N	%
Cases	Valid	114	44.7
	Excluded[a]	141	55.3
	Total	255	100.0

a. Listwise deletion based on all variables in the procedure.

Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items	N of Items
.536	.537	6