UNIVERSITY OF CAPE COAST

AN INVESTIGATION INTO SCIENCE PRACTICAL WORK IN SENIOR SECONDARY SCHOOLS: ATTITUDES AND PERCEPTIONS

BY

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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.

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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

The use of practical activities in science has been accepted as part of the science teaching and learning in Ghanaian Senior Secondary Schools albeit for different reasons. Over the years, the West African Examination Council (WAEC) Chief Examiners' reports have consistently alluded to weaknesses in students' performance in science practical examinations. These weaknesses have cast serious doubts on Senior Secondary School (SSS) students' involvement in practical activities during their science course and giving the impression that they were either not taken through the practical activities or did not take them seriously.

This study is aimed at investigating the factors that might contribute to students' weaknesses in science practical work and how they can be addressed. This was done through descriptive, inferential as well as explanatory information on students' perception of their psychosocial laboratory environments; their attitudes to science practical work; teachers' views on the purpose of science practical work and how it is organised. The study employed the survey method and qualitative approach to collect data.

Some of the key findings that emerged in this study were:

1. Factors influencing students' perception of their psychosocial science laboratory environments were supply material environment, reliable material environment, integration, and supervision.

2. Factors influencing students' attitudes towards science practical work were learning tool, equipment and interest.
3. Students' perceptions of their laboratory environment and attitudes towards science practical work were significantly different in favour of students from SRC schools. The significant difference in perception was due to the different material environments in the two school types. The difference in attitude of students was due to interest in science practical work and the provision of equipment.
4. No relationship was found between students' attitude to science practical work and their perception of the science laboratory environment.
5. Teachers' views on the purpose of practical work were mainly that of discovering or elucidating theory taught in class; SRCs are not playing the required role of supporting science practical activities due to poor patronage arising from several constraints.
6. Students did not have enough science practical activities due to lack of time, overloaded curricula, lack of equipment and large class sizes
7. Much attention was not paid to supervision of students by their teachers during science practical activities.

These findings may account for some of the students' weaknesses in science practical examinations reported by Chief Examiners.

Evidence from the findings was then used as a basis for conclusions about addressing the situation in the schools. Recommendations for Ministry of Education and Ghana Education Service, WAEC, and curriculum developers and potential areas for further research were also made.

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Finally, to the Lord Jesus, to him I owe everything. To God be the Glory.

DEDICATION

To my wife, Regina and children, Emmanuel and Edwina for their encouragement and patience during the course of my studies.

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LIST OF ABBREVIATIONS

ASP	Attitude towards science practical
CRDD	Curriculum, Research and Development Division
ESLEI	Environmental science learning environment inventory
GES	Ghana Education Service
HOD(s)	Head of Department(s)
IPHOD	Interview protocol for heads of science departments
IPS	Interview protocol for students
IPSC	Interview protocol for SRC co-ordinators
MOE	Ministry of Education
QOSP	Questionnaire on the organisation of science practical work
QRSP	Questionnaire on the role of science practical work
SAT	Satellite school
SLEI	Science laboratory environment inventory
SLEQ	Science laboratory environment questionnaire
SRC	Science Resource Centre
SSS	Senior Secondary School
SSSCE	Senior Secondary School Certificate Examination
WAEC	West African Examinations Council

CHAPTER 1

INTRODUCTION

Background to the Study

Practical work occupies an important place in the education of science students. It is based on the assumption that learning by doing is best for acquiring process skills. Science practical work may involve several facets such as illustrations of a phenomenon; providing experiences or getting a feel of phenomenon; exercises or routines for students to follow; developing a particular skill or becoming used to a piece of equipment or instrument. Early practical activities were essentially demonstrations aimed at the acquisition of observational and manipulative skills, and for training in the use of equipment.

One way of looking at the aims of practical work is to categorize them broadly into those related to developing practical skills and attitudes, and those related to discovering or elucidating theory (Woolnough, 1998). The latter make use of structured experiments linked to theory. Those who argue in favour of practical activity are however, divided on its aims and how it should be organized so as to help students. They differ greatly in what skills are important and how they can be achieved. Some rate the aims related to practical skills more highly than those related to developing theoretical work. Presently, practical activities could be provided through the use of either the conventional approach or computer-assisted approach. Computer -assisted practical work relates to the use of sensors, interfaces and software to monitor and display data collected during science practical activities. The conventional approach includes the use of standard laboratories, science kits, teacher demonstrations, and field activities. Some science educators who advocate the use of conventional approach to practical activities insist that science practical should be laboratory-based whilst others advocate for practical activities that are not necessarily based in laboratories. Those who insist on laboratory-based practical work assert that emphasis on acquisition of laboratory skills may be especially important for improving students' ability to design experiments to solve problems. Apart from using laboratory-based practical work to solve problems, von Secker and Lissitz (1999) are of the opinion that laboratory-based practical activities promote the development of process skills. They therefore argue against the use of teacher demonstrations as well as large group instruction as a way of facilitating the development of process skills. In fact, Tamir and Lunetta (1981) think that laboratory-based practical activity covers more areas of competencies when they emphatically stated that the main purpose of the laboratory is to afford experiences and challenges for students to solve problems, construct relevant science knowledge, undertake scientific investigations, promote inquiry and verify known scientific concepts and laws. However, according to Knott and Mutunga (1995) during the past twenty-five years a major re-appraisal of uses and methods in laboratory teaching has taken place. They have noted that there is considerable controversy about the use of laboratories for the learning of process skills. Some of the areas of concern raised by Knott and Mutanga (1995) are:

1. the high cost of laboratory work, making it difficult to continue providing facilities and resources to the standard felt necessary;
2. severe time constraints and overloading of timetables leading to serious problems in meeting syllabus requirements in quality and quantity;
3. dissatisfaction with the effectiveness of conventional laboratory work, which does not foster the understanding of scientific concepts and the application of scientific principles to solving problems. (p. 186)

Several comparative studies of conventional laboratory classes and other forms of teaching indicate shortcomings in the effectiveness of laboratory work. Although laboratory work is thought to be more effective than other methods for acquiring observational and manipulative skills, others have argued that it is generally less effective for teaching factual knowledge, concepts, scientific enquiry or problem solving skills (Knott & Mutunga, 1995; Lewin, 1992). In fact, Edmondson and Novak (1993) think that science laboratory work is nothing more than learning "bench techniques" (p. 551). According to them almost half a century ago, summaries of research on the value of laboratory work experience for learning science did not favour the laboratory over lecture-demonstration. This is contrary to claims made by von Secker and Lissitz (1999) who argued for laboratory-based science practical work. Some earlier studies by Stake and Easley (1978), Bogden (1977), Buchweitz (1981), and Waterman (1982) have also showed that most students in laboratories gained very little either regarding key science concepts or toward understanding the process of knowledge construction. Lewin (2000) has observed that "the role of practical activity in science is often confused with laboratory work" (p. 22). His argument is that "active engagement with problems in the physical world is part of everyday experience and most, if not all, worthwhile thinking skills associated with secondary science can be taught without expensive equipment" (p. 22) and hence without the use of a laboratory. Barton (1998) has also argued that the scope of practical work done (in laboratories) is limited by logistical factors such as equipment and time. He emphasizes that practical work should be geared toward the analysis and interpretation of data instead of merely collecting and processing data. Ross and Lewin (1992) writing on the role and impact of practical work cite the work of Yager, Engen and Snider, which suggests that laboratory activity does not fulfill the various functions expected of it, except perhaps for the development of manipulative skills. They argue that if the only skills that laboratory activity can achieve are manipulative skills then it is not worth committing resources to laboratories. According to Ross and Lewin (1992), laboratories seem divorced from the materials and experiences that students encounter in their daily lives. They therefore suggest that a substantial proportion of laboratory investigations must use common materials encountered by students in every day life. In this way it might be possible for students to achieve the various functions expected of them. Ross and Lewin conclude by suggesting that

> it is the aims, content and implementation of practical work in science that have to be reviewed, including the need to redesign science rooms and science equipment to incorporate more of the materials from nature's laboratory so that students have more opportunity to explore the properties of everyday materials and the scientific principles embedded in everyday phenomena. (p. 10)

This perspective taken by Barton (1998), Ross and Lewin (1992) and some other science educators has led to the promotion of demonstrations, science kits, computer-assisted practical work and other conventional methods with more experiential and discovery-based strategies, which are not necessarily laboratory-based.

The main reasons given to justify practical work in science education can be encapsulated in a number of ways. Wellington (1998) identifies three reasons in favour of practical activity:

(a) practical work can improve pupils' understanding of science and promote conceptual development;

(b) practical work is motivating and exciting and helps learners to remember things;

(c) practical work develops not only manipulative skills or manual dexterity skills, but also promotes higher level, transferable skills such as observation, measurement, prediction and inference.

There are counter arguments to the above reasons as some researchers and science educators do not agree to some or all of the above arguments. For example, on the first argument some people argue that practical work can confuse as easily as it can clarify or aid understanding, especially if it goes wrong. In addition to this, they argue that practical work is not a good tool for teaching theory since theories are about ideas and objects. The thinking that goes into such an argument is that theories involve abstract ideas, which cannot be physically illustrated. In the words of Theobald cited in Wellington (1998) "experience does not give concepts meaning, if anything, concepts give experience meaning" (p. 7). Leach and Scott (1995) sums it up in this way: "In the context of the school laboratory it is clear that students cannot develop an understanding through their own observations, as the theoretical entities of science are not there to be seen" (p. 48). One of the counter arguments to the second argument stated above is that some students are rather 'turned off' by practical work instead of it helping them to remember things. In fact, a study by Murphy cited in Woolnough (1991) indicates that more girls than boys react negatively to practical work in science. Woolnough (1998) for example, has argued against the use of practical work in helping students understand both the concepts of science and the process of science at the same time. So for over 100 years that practical work has been a part of science, its function has been the subject of debate and disagreement among science educators (Barton, 1998).

Whatever views are expressed about the purpose of practical work, and in spite of different opinions about its role, many teachers may see practical work as offering an essential opportunity for students to link first-hand experience in the form of practical work with concepts and ideas. Perhaps it is in line with this thinking that the examination and teaching science syllabuses for Senior Secondary Schools (SSS) produced by the West African Examinations Council (WAEC) and Curriculum Research and Development Division (CRDD) of the Ghana Education Service (GES) respectively have placed emphasis on the value of practical work and developing familiarity with experimental methods among students. A key issue in the reform efforts of the Ministry of Education (MOE) aimed at promoting the learning of science in all schools is by providing students with equal opportunity to engage in science practical work. It is expected that allowing students to experience the process of scientific enquiry can develop an understanding of science and its nature. Practical work is therefore, an integral part of the science curriculum at the SSS level in Ghana.

In spite of all the arguments against practical work, Barton (1998) concedes that there is no substitute for experiencing science at first hand as this assists in developing an understanding of scientific phenomena. Barton admits "practical work has the potential to challenge pupils' ideas and to draw them into learning about science" (p. 240). Perhaps it is in line with this admission by Barton that the MOE has towed the line for the development of process skills in particular and the teaching and learning of science in general through the use of well-equipped laboratories. The WAEC chemistry syllabus for example, mentions the availability of well-equipped laboratories as a pre-requisite for schools pursuing chemistry at the SSS level. Unfortunately, in Ghanaian SSS, there are significant inequities in opportunities for access to laboratory experiences due to inadequate facilities and equipment, and lack of money to purchase consumable supplies such that SSS have been categorized into well-endowed and less-endowed schools. This officially endorsed categorization may create larger gaps among students, because students in disadvantaged schools may generally have fewer opportunities for scientific inquiry.

To address issues surrounding inequitable opportunities for effective science course (which involves practical work), a policy option taken by the MOE was to create special centres called Science Resource Centres (SRCs) stocked with adequate resources and sited in selected SSS. These SRCs act as satellite centres, which serve surrounding SSS, which lack the needed resources for science practical work. Documents available from the office of the National Co-ordinator for SRCs indicate that presently the centres are based in 107 selected SSS in the country and service schools in their locality. These centres have been equipped with basic science equipment including modern electronic devices and computers to be used in the teaching and learning of science. Buses have been provided to all SRCs for use by satellite schools. Schools are required to pay user fees (which are charged to students) before they are allowed to use the centres. The centres' own teachers teach all students who go there. The project is a collaborative effort between the Ghana government and Philip Harris International of Britain with the Ghana Government providing the funds whilst Philip Harris International provided the equipment and technical expertise. Under the agreement, the Ghana Government rehabilitated and refurbished old laboratories in the selected schools and Philip Harris International supplied and installed science equipment in those selected centres.

The objectives of the SRCs at the District level include the following:

(i) to serve as teaching centres to supplement existing facilities in secondary schools and give ample opportunities for practical work using modern facilities and techniques including the use of computers

(ii) to provide additional tuition facilities for students in schools without well-equipped laboratories

(iv) to expose students and teachers to the use of computers and other electronic equipment in the teaching of science

(Status Report of the Science Resource Centres Project, 1997, p. 2)

Statement of the Problem

In the last section, it was argued that the MOE and WAEC syllabuses emphasize the acquisition of scientific skills (e.g. accurate observation, measurement and recording), and scientific attitudes (e.g. concern for accuracy, objectivity, integrity, initiative etc) through practical work in biology, physics and chemistry. In line with this, provision has been made for science practical work to take place in schools by the establishment of SRCs to cater for both well-endowed and less endowed schools. Yet WAEC Chief Examiners for physics, chemistry and biology have over the years reported of students' weaknesses in science practical examinations. A variety of specific students' weaknesses in the practical examination reported by Chief Examiners cast serious doubts on SSS students' involvement in practical activities during their science course. This gives the impression that they were either not taken through the practical activities or did not take them seriously. Some of the persistent weaknesses identified over the years (1995-2001) by Chief Examiners for the sciences are quoted below:

(a) candidates were incapable of critical analysis and interpretation of biological data

(b) candidates have not been having adequate practical as was shown by the answers provided

(c) it was clear from the answers that some candidates had not done any experiments along the lines tested at all

(d) Candidates generally made statements which clearly demonstrates that the suggested activities in the syllabus are not being carried out with any seriousness

(e) most candidates could not show any sign of having done a simple recrystallisation in their lives.

This is happening in spite of the fact that SRCs have been established for both host and satellite schools to serve as teaching centres to supplement existing facilities in secondary schools and give ample opportunities for practical work using modern facilities and techniques including the use of computers. It is uncertain whether the fault lies with the way science teachers organise science practical activities or the frequency with which they are organised. It is also likely that students' attitude to practical work or their perception of the science laboratory environment have affected their interest and hence their performance.

It would be desirable therefore, to investigate issues concerning science practical work at the SSS level, in order to help shed some light on what may be possible reasons why students perform very poorly in science practical examinations despite the provision of very expensive laboratory equipment and materials for students in SRC and satellite schools in the name of promoting scientific literacy and helping students to do well in science.

Purpose of the study

This study aims at investigating some of the factors contributing to students' weaknesses reported by WAEC Chief Examiners on Science Practical Examinations (see Appendices A1, A2 and A3) and how they can be addressed. The purpose of this study is therefore to:

1. determine factors if any, underlying students' perception of their psychosocial science laboratory environment

2. determine factors if any, underlying students' attitude towards science practical work

3. find out whether:

   (a) students from SRC and satellite schools perceive their psychosocial science laboratory environments differently;

   (b) attitude of students from SRC and satellite schools towards science practical work differ significantly.

4. determine whether associations exist between students' perceptions of their science laboratory environments and their attitudes towards science practical work

5. find out:

   (a) what science teachers consider to be the essential purposes of science practical activities in the teaching and learning of science

   (b) how science teachers organise science practical activities.

<u>Research Questions</u>

Specifically, in this study an attempt was made to answer the following research questions:

1. What factors, if any, underlie students' perception of their psychosocial science laboratory environment?
2. What factors, if any, underlie students' attitude towards science practical work?

3. Is there any significant difference between students' perception of their psychosocial science laboratory environment in SRC and satellite schools?
4. Is there any significant difference between students' attitude towards science practical work in SRC and satellite schools?
5. Is there any significant relationship between students' attitude to science practical work and their perception of their psychosocial science laboratory environment in SRC and satellite schools?
6. What do teachers consider to be the essential purposes of science practical work in the teaching and learning of science?
7. How do teachers organise science practical activities to promote the learning of science?

Null Hypotheses

The following null hypotheses have been formulated for testing:

1. There is no significant difference between students in SRC and satellite schools in their perceptions of their psychosocial science laboratory environment.
2. There is no significant difference between students in SRC and satellite schools in their attitude towards science practical work.
3. There is no significant association between students' perception of their psychosocial science laboratory environment and their attitude towards science practical work in SRC schools.

Significance of the Study

First, this study has illuminated factors which affect students' perceptions of their psychosocial science laboratory environment and attitudes toward the science practical activities in Ghanaian SSS in the Central Region. It will therefore provide information about what emphases in the science laboratory environment will promote positive student attitudes and perceptions. This will provide the MOE/GES, science teachers and Heads of SSS with information which will enable them adopt strategies that might improve students' attitudes to science practical work as well as the learning environment of science laboratories.

Secondly, the study has will unearthed and documented practices and situations in both satellite and SRC SSS which might give some insight into factors contributing to the low performance in WAEC practical examinations reported by Chief Examiners.

Thirdly, this study provides useful information on how science practical activities are organised in Ghanaian SSS, and the role they play in the teaching and learning of science from science teachers' perspective. This study will therefore, not only make an important contribution to the study of science through laboratory activities, but will also contribute to improving the teaching and learning of science in laboratories. It is pertinent to note that contexts for science education differ substantially from one culture to the other, and that there has been a considerable amount of work on how science and scientific ideas are perceived in different cultures (Lewin, 1992). This study will therefore contribute to the debate on the role of laboratory-based practical activity and its impact on effective teaching and learning of science in SSS in the Ghanaian context.

Finally, this study will have significance for future policy formulation in Ghana on the nature and use of laboratory-based practical work to facilitate the teaching and learning of science and will be useful for appraising the use of laboratory-based practical activities in the teaching and learning of science in Ghana.

Delimitation

There were a total of 49 SSS offering all three elective science subjects (in the Central Region of Ghana at the time of this study. The study confined itself to only the 18 schools which were offering all three elective science subjects (physics, chemistry and biology) for the WAEC examinations as the population of interest. Only science students in SSS3 were used in this study since these students had done the three elective science subjects for a period of almost three years and were therefore in a position to share their views on science practical activities over the almost three year period compared to students in SSS1 and SSS2. In the collection of data using qualitative methods, this study confined itself to the use of interviews only of science students, Heads of Departments and SRC Co-ordinators.

Limitations

Despite the obvious advantages of integrating quantitative and qualitative data by the use of different methodologies, the two methodologies (quantitative and qualitative) are based on different assumptions. Some of the survey and case study findings at times seem conflicting. This is to be expected since situations in all schools may not fall in line with generalisations from the survey.

Another limitation was the restriction imposed on the data because of the decision to focus on only schools, which offer all three science electives. Subject selection at the SSS level allows schools to offer one or two of the three elective science subjects. Although it is possible that there could be some differences in the attention given to practical work in such schools, the differences will not be so wide as to undermine the validity of the study.

Finally, the focus on four case study schools out of a total of 18 schools places a limitation on the study. This was due to limited financial resources, and time at the researcher's disposal. However, from my experience as a former science teacher at the SSS level in Ghana, to a large extent the findings in this study are a fair representation of the situation in many Ghanaian SSS. The idea of using case studies was to understand issues about practical work in schools within the context of the four SSS. Since the basic conditions are the not very different, the key issues will still be relevant for the vast majority, if not all the other SSS.

Organisation of the Rest of the Thesis

The thesis has four additional chapters, which have been logically arranged to provide insights into the issues raised in this section and to provide answers to the research questions. Chapter two of the thesis is devoted to a general review of the relevant literature on issues relating to the study, namely, history of science practical work, its role and organisation as well as attitudes, and perceptions of students. The final part of chapter two looks at the concept of the SRC model in addressing inequities in science equipment between well-endowed and less endowed SSS.

Chapter three discusses the research methodology for the study. It describes the type of study and design in detail, and the rationale for the design. The strengths and weaknesses of the design are also discussed. Issues relating to population and sampling, instruments, data collection procedure, and data analysis are also discussed in detail.

In chapter four, the results of the study are presented and discussed under two main parts. The first part presents the findings of the survey data across 10 schools and discusses them under Quantitative Analysis. The second presents the findings of the multi-site case studies across four schools and discusses them under Qualitative Analysis. The chapter contains extensive use of verbatim quotations from students, HODs and SRC Coordinators to illustrate the perspectives of participants in the research and is in keeping with the traditions of reporting qualitative case study evidence (Akwesi, 1994).

In Chapter five, an overview of the research problem and methodology are given. A summary of the key findings and their interpretations with reference to the literature are also provided. Implications and conclusions relating to the findings are also discussed. In addition, the issues unearthed for possible future research are presented. A humility section specifying limitations of the study in terms of the internal and external validity of the research design and generalisability of the findings respectively are included.

CHAPTER 2

REVIEW OF LITERATURE

Overview

The purpose of this chapter is to review and discuss issues in the literature relating to science practical activities. For the purposes of the study, the review is organised around the following sub-headings:

(a) Historical review of science practical work

(b) The nature of senior secondary school science curriculum

(c) Role of practical work in the teaching and learning of science

(d) Organisation of science practical work

(e) Use of group work in the science laboratory

(f) The Science Resource Centre model

(g) Attitude of students towards science practical work

(h) Students psychosocial perception of their science laboratory environment

Historical Review of Science Practical Work

The literature shows that laboratories for the conduct of scientific research have existed at least since the seventeenth century. However, according to Jenkins (1998), the use of the science teaching laboratory, designed and equipped to teach science to students, is essentially a nineteenth-century phenomenon. Prior to this period, notably in the seventeenth century, analytical laboratories were common in many European countries, in universities and mining academies (Abdalla, 1991). However, according to Abdalla, in the United Kingdom, the essential stimulus to practical teaching in those days was a medical one, which began in Scotland, Glassgow and Edinburgh. This medical reason for teaching practical work was introduced in London by Edward Turner and Thomas Graham. In 1844 therefore, a huge teaching laboratory of the Pharmaceutical Society was established.

According to Abdalla (1991), at that time the purpose for establishing expensive laboratories to teach practical science to undergraduates was not clear. During those days, science was taught mainly by memorising information in textbooks, and when textbooks were not available, the teaching frequently involved students in no more than copying down verbatim notes dictated slowly by the class teacher (Abdalla, 1991).

In the nineteenth century, the introduction of laboratory work and for that matter practical work in the sciences started with the teaching of chemistry at the undergraduate level. Pioneering work done in the nineteenth century by Thomas Thomson in Britain led to the establishment of the first undergraduate course in practical chemistry at Glasgow in 1818 (Duff, 1997). Practical work was seen as a vehicle for training the mind and developing the skills of observing, reasoning and so on, which were deemed to be of general value. Before then, the teaching of science particularly at the undergraduate level in universities in Britain was mainly by means of lectures, which were sometimes enlivened by means of demonstrations intended to capture the attention of as many students as possible.

When Edward Frankland, was appointed the Chair of Chemistry at the Royal College of Chemistry, which was opened in 1845, he succeeded in persuading the Department of Science and Art to provide grants for science laboratories. He however, found it was useless to equip laboratories and set up experiments while teachers lacked laboratory experience, so he began a summer school for teachers. In 1875 Frankland published his book "How to Teach Chemistry". The book described 109 experiments that he believed all students should be shown by teachers. This then became the chemistry practical syllabus for schools for two decades (Lynch, as cited in Abdalla, 1991).

According to Abdalla (1991), an "x-Club", a group of nine men whose aim was to change science education to one that was more practically based, was set up in England. The influence of this group was very considerable with H.E Armstrong as a key figure. His interest in science teaching stemmed from his experience of teaching chemistry to medical students, who, he found, were unable to interpret simple experimental data. This, and later experiences, convinced him of the unsatisfactory nature of the science education being received by students. The approach he advocated was one, which would allow students to learn through discovery (Windeatt as cited in Abdalla, 1991).

In the mid-nineteenth century, science examiners of the Oxford and Cambridge Local Examination Boards highlighted the importance of teaching science in the laboratory. Notable among the science examiners was Edward

Frankland who reported that the unsatisfactory results of the examinations in the elementary stage were due to the lack of sufficient illustrations during teaching. Grants were therefore provided by the Department of Art and Science to build laboratories and purchase equipment. During the last quarter of the nineteenth century therefore, resources were provided on a significant scale to support the provision of school science laboratories for the teaching of practical skills and the use of demonstrations. It was therefore declared that the instruction of scholars in science subjects shall be given mainly by experiments (Hodson, 1990).

In the latter part of the nineteenth century, practical teaching of science was extended to physics. Laboratories for teaching undergraduate physics presented different problems from chemistry. This is because compared with chemistry, physics embraced a wider variety of experimental activities that were not readily accommodated within a single laboratory. Physics equipment were often both delicate and expensive, as physics and was based upon accurate observation and precise measurements.

After physics, botany came to be taught using the experimental approach. The teaching of botany (plant morphology and taxonomy) came to be taught using the experimental approach because of its direct relationship with everyday experience. Since that time, the major science curriculum developments have promoted practical work as an enjoyable, effective form of learning (Hodson, 1990).

From the beginning of the 20th Century there was continuous increase in facilities and equipment suitable for practical science teaching. The 1914-1918 war opened the eyes of people to the importance of science teaching. This awareness of the importance of science became more prominent after the Russians launched their first satellite (Sputnik) in 1957. In the 1960s, another cycle of science curriculum development began in the United States of America and concentration on laboratory work increased. New American and English curricula spread to different parts of the world including Africa. By the late 1950s, some initiatives were taken which led to the large-scale curriculum reform movements in the 1960s in England and Wales. This was first funded by the Nuffield Foundation, and later by the Schools Council, set up in 1964 (Jenkins, 1998). According to Jenkins, in the Nuffield Projects pupils were, "as far as possible, to engage in investigative activities and, thereby gain vicarious experience of scientific discovery" (p. 46). This project lent important support to the idea that had already been mooted that all science teaching should be laboratory-based.

In Africa prior to the 1950s, laboratory work was used to demonstrate and confirm knowledge as in Europe. The textbook was the curriculum and hence what passed as the teaching of science was nothing more than information-giving by teachers and memorisation of the presented information by students. The theoretical approach to teaching science was further encouraged by the emphasis it received in public examinations (Ajeyalemi, 1990). However, since the 1980s, attempts have been made in Africa as a whole and Ghana in particular to use laboratory exercises to provide opportunities for students to solve problems, learn enquiry processes and develop decision-making skills. Specifically, the WAEC imposed conditions in the science examinations to ensure practical orientation of the science courses in the secondary schools. Each of the science subjects (physics, chemistry and biology) consisted of a theory paper and a practical paper. Each practical paper was based on the content of the particular science subject. This was "intended to determine how well the candidates understand the nature of scientific investigation and the use of apparatus in a controlled experiment to determine an answer to a question" (Collins & Aidoo-Taylor, 1990, p.17). The WAEC syllabus for example, requires the availability of well-equipped laboratories as a pre-requisite for schools pursuing science courses.

In summary, the development of science practical laboratories and the use of practical activities as part of the teaching and learning of science has evolved slowly since the nineteenth century. This began with chemistry. The evolution of practical activities started in Europe and was extended to America and Africa and became a serious issue in the 1960s. Presently, practical activities in science have been accepted as part of the science teaching and learning albeit for different reasons.

The Nature of Practical Work in Ghanaian SSS Science Curriculum

Science practical activity has become an integral part of most new science programmes in developing countries according to reports of the 9th and 10th

International Clearing House on Science and Mathematics Curriculum Development (Lockard as cited in Lewin, 1992). The science syllabuses for Ghanaian SSS prescribed by CRDD and WAEC have a practical activity component to be conducted in a laboratory setting. The CRDD document is a teaching syllabus whilst the WAEC document is an examination syllabus. The SSS syllabus from the WAEC from 1998 to 2002 emphasizes the acquisition of some skills by means of practical work in biology, physics and chemistry as follows:

<u>Biology</u>

(a) acquisition of adequate laboratory and field skills in order to carry out and evaluate experiments and projects in biology;

(b) acquisition of the necessary scientific skills for example, observing, classifying and interpreting biological data.

<u>Physics</u>

(a) carry out experimental procedures using apparatus;

(b) develop abilities, attitudes and skills that encourage efficient and safe practice;

(c) make and record observations, measurements and estimates with due regard to precision, accuracy and units.

<u>Chemistry</u>

development of laboratory skills including an awareness of hazards in the laboratory and the safety measures required to prevent them.

The objectives of the science curriculum listed here are those that are tied to the context of a laboratory. To achieve these objectives, students must of necessity use the conventional approach of doing science in a laboratory. According to Osborne (1998), this kind of emphasis on laboratory work is "strongly associated with the conception that scientific knowledge is lying around out there to be discovered by the curious" (p. 171). This idea of tying science education to the laboratory has been the practice and culture of science teaching since the nineteenth century as discussed in the previous section. It is therefore not surprising that the WAEC and CRDD curriculum place emphasis on the manipulation of a plethora of standard apparatus, the gathering of experimental data and the acquisition of varied laboratory skills, which can only be acquired through laboratory work. According to Osborne, only a "radical surgery will force a re-examination of the cultural sclerosis that pre-dominates in the teaching of science where the adherence to the laboratory blocks progression in our pedagogy" (p. 172).

However, Knott and Mutunga (1995) have reported that during the past twenty-five years a major re-appraisal of uses and methods in laboratory teaching has taken place. They have noted that there is considerable controversy about the use of laboratories for the learning of process skills. Some of the areas of concern raised by Knott and Mutanga are:

1. the high cost of laboratory work, making it difficult to continue providing facilities and resources to the standard felt necessary;

2. severe time constraints and overloading of timetables leading to serious problems in meeting syllabus requirements in quality and quantity;
3. dissatisfaction with the effectiveness of conventional laboratory work, which does not foster the understanding of scientific concepts and the application of scientific principles to solving problems (p. 186).

Several comparative studies of conventional laboratory classes and other forms of teaching indicate shortcomings in the effectiveness of laboratory work. Although laboratory work is thought to be more effective than other methods for acquiring observational and manual skills, others have argued that it is generally less effective for teaching factual knowledge, concepts, scientific enquiry or problem solving skills (Knott & Mutunga, 1995; Lewin, 1992). In fact, Edmondson and Novak (1993) think that science laboratory work is nothing more than learning "bench techniques" (p. 551). According to them almost half a century ago, summaries of research on the value of laboratory work experience for learning science did not favour the laboratory over lecture-demonstration, contrary to such claims made by von Secker and Lissitz (1999). Some earlier studies by Stake and Easley (1978), Bogden (1977), Buchweitz (1981), and Waterman (1982) also showed that most students in laboratories gained very little either regarding key science concepts or toward understanding the process of knowledge construction. Lewin (2000) has therefore, observed that "the role of practical activity in science is often confused with laboratory work" (p. 22). His argument is that "active engagement with problems in the physical world is part of everyday experience and most, if not all, worthwhile thinking skills associated with secondary science can be taught without expensive equipment" (p. 22) and hence without the use of a laboratory. Barton (1998) has also argued that since the scope of practical work done (in laboratories) is limited by logistical factors such as equipment and time, practical work should be geared toward the analysis and interpretation of data instead of merely collecting and processing data. Ross and Lewin (1992) writing on the role and impact of practical work cite the work of Yager, Engen and Snider which suggests that laboratory activity does not fulfill the various functions expected of it, except perhaps for the development of manipulative skills. They argue that if the only skills that laboratory activity can achieve are manipulative skills, then it is not worth committing resources to laboratories. According to Ross and Lewin (1992), laboratories seem divorced from the materials and experiences that students encounter in their daily lives. They therefore, suggest that a substantial proportion of laboratory investigations should use common materials encountered by students. In this way it might be possible for students to achieve the various functions expected of them. Ross and Lewin conclude by suggesting that

> it is the aims, content and implementation of practical work in science that have to be reviewed, including the need to redesign science rooms and science equipment to incorporate more of the materials from nature's laboratory so that students have more opportunity to explore the

properties of everyday materials and the scientific principles embedded in everyday phenomena (p. 10).

This perspective taken by Barton (1998), Ross and Lewin (1992) and some other science educators support the promotion of demonstrations, science kits, computer-assisted practical work and other non-conventional methods with more experiential and discovery-based strategies, which are not necessarily laboratory based.

However, there are other objectives stated in the science syllabuses, which relate to the acquisition of scientific skills but do not necessarily need conventional laboratories to achieve them. These objectives are summarized as follows:

(a) acquisition of the necessary scientific skills for example, classifying and interpreting biological data.

(b) acquisition of scientific attitudes for problem solving

(c) appreciation of the scientific method which involves deduction and interpretation of scientific data;

(d) development of attitudes relevant to science such as concern for accuracy and precision, objectivity, integrity, initiative and inventiveness.

(e) development of scientific skills and attitudes as pre-requisites for further scientific activities.

This means that apart from laboratory skills, the syllabuses therefore stress the acquisition of skills that would enable students draw conclusions from experimental results, and the development of interest and the enjoyment of the science subjects. The ability to interpret and reason would also enable students develop understanding of the scientific concepts and procedures. These skills are important and central to developing an understanding of the nature of science and the skills of synthesis and critical evaluation, fundamental for participation in a scientific society (Osborne, 1998). It is therefore obvious that the science syllabuses for SSS place emphasis on both laboratory-based skills and general scientific skills. Table 1 gives a summary of science practical skills contained in the SSS WAEC and CRDD elective science syllabuses.

Table 1

A summary of practical skills for SSS elective science as outlined by WAEC and CRDD syllabuses

		Skills	
Process	Biology	Chemistry	Physics
Planning	Carrying out and evaluating experiments and projects	Experimental design	Identifying problems, plan and carry out investigations including selection of techniques, apparatus,

Table 1 cont'd

	Skills		
Process	Biology	Chemistry	Physics
			measuring devices and materials
Performing	Observing; classifying; adequate laboratory and problem solving skills	Accurate observation, observing and recording; Laboratory skills	Make and record observations, measurements and estimates with due regard to precision, accuracy and units
Interpreting	Interpreting biological data	Deduction and interpretation of scientific data	Interpret, evaluate and report on observations and experimental data
Scientific Attitudes	Scientific attitudes for problem solving	Scientific attitudes such as awareness of hazards in the laboratory and safety measures	Scientific attitudes and skills that encourage efficient and safe practice; concern for accuracy

Table 1 cont'd

	Skills		
Process	Biology	Chemistry	Physics
			and precision; objectivity; integrity; initiative and inventiveness

Chief Examiners' Reports on Performance in Science Practical Examinations

The SSS science syllabuses from the WAEC emphasise the acquisition of scientific skills (e.g., accurate observation, measurement and recording), laboratory skills as well as scientific attitudes (e.g., concern for accuracy, objectivity, integrity, initiative etc.). It is therefore expected that students would go through the science syllabuses, which include practical work in preparation for the final WAEC science practical examinations. With the provision of SRCs it is also expected that students in disadvantaged schools would have the opportunity to undertake practical activities.

However, a variety of specific students' weaknesses in the practical examination reported by Chief Examiners cast serious doubts on SSS students' involvement in practical activities in the schools. This gives the impression that students are either not taken through practical activities or did not take them seriously. Some of the persistent weaknesses identified over the years (1995-

2000) by the Chief Examiners for the sciences are as follows:

<u>Biology</u>

(a) candidates were incapable of critical analysis and interpretation of biological data

(b) candidates have not been having adequate practical work as shown by the answers provided

(c) candidates should follow the question and do exactly what is demanded

(d) standard of drawing was very poor

(e) most candidates could not draw diagrams from observation of specimen

(f) inability to design simple experiments

(g) description of graphs drawn were inaccurate and explanation of the data provided for the graphs was poor

<u>Chemistry</u>

(a) candidates showed clearly that they had not been exposed to some of the activities suggested in the syllabus

(b) some of the candidates did not see the need to carry out the tests in the order specified in the questions

(c) it was clear from the answers that some candidates had not done any experiment along the lines tested at all

(d) most candidates did not show any sign of having done a simple recrystallisation in their lives

(e) most candidates could not make correct deductions from the observations of the tests they performed.

(f) Candidates generally made statements of facts which clearly demonstrates that the suggested activities in the syllabus are not being carried out with any seriousness

(g) Some candidates did not have enough practical exposure

(h) Most candidates were found wanting in the way they recorded their tests and observations

Physics

(a) many candidates did not present their units in the standard form. They must be taught that whether the units are in a table, graph or final results of experiments, it is neater and clearer to be presented in the standard form

(b) some candidates chose awkward scales with the result that plotting of graph was difficult

(c) poor labelling of axes and the omission of units on the axes

(d) candidates could not use measuring instruments to measure accurately

This is happening in spite of the fact that SRCs for both host and satellite schools have been established to serve as teaching centres to supplement existing facilities in secondary schools, to give ample opportunities for practical work by students using modern facilities and techniques including the use of computers.

Role of Practical Work in the Teaching and Learning of Science

Advocates of science practical work contend that it is advantageous for:

(a) student learning of scientific knowledge and methods of science;

(b) student acquisition of scientific skills;

(c) motivation; and

(d) the acquisition of scientific attitudes

The literature pertaining to each of these reasons is extensive and conflicting as there are arguments supporting and refuting each of the rationale that has been stated. The purpose of this review is not to catalogue the various arguments for and against science practical work. This is because science practical has been accepted to be part of the science curriculum for Ghanaian SSS by the MOE and WAEC. The issue therefore is, given that practical work must be done, what purposes does it serve and is there an agreement in the literature as to what the role of practical activities must be in order to promote the teaching and learning of science? It is expected that practical work should promote cognitive and social competencies as well as affective dispositions. According to Ben-Zvi (1991), practical work at the secondary school level has been influenced by two opposing philosophies: (a) the use of experiments as a means for verification of previously studied facts, and (b) the laboratory as the focus of the learning process where experiments are presented as problems to which answers are to be sought. In the latter case the teaching of science is centred on the laboratory. The major problem of centering the study of science around the laboratory is that it is both expensive in resources and student time. Presently there seems to be a growing concern that although the laboratory cannot be disposed of entirely, its role in science education should be reassessed. As already noted, analysts differ in their opinions about the role of practical work because of their different views about learning theory (Ross & Lewin ,1992).

According to Woolnough (1998) one way of looking at science practical activities is to categorize them broadly into those related to developing practical skills and attitudes; and those related to discovering or elucidating theory. The latter makes use of structured experiments linked to theory. Those who argue in favour of practical activities are however, divided on its aims and how it should be organized so as to help students. They differ greatly in what skills are important and how they can be achieved. Some rank the aims related to practical skills more highly than those related to developing theory and vice versa. In two major research exercises in the 1960s and 1970s reported by Millar (1998), teachers were asked to rank in order of importance lists of possible aims of practical work. Two of the main groups of aims identified are those, which concern the role of practical work in supporting the teaching of scientific knowledge, and in teaching about the processes of scientific enquiry. As noted by Millar (1998), "an investigative or enquiry approach encourages children to be more independent and self-reliant, to think of themselves as able to pose their own questions about the physical work and to find answers to them through their own efforts" (p. 17). It seems that much of what is said about practical work stems from this view about the use of the enquiry approach to teach science. In reality what the practical work does is simply to reproduce a phenomenon, which has already been established (Millar, 1998). However, as noted by Hacking (1983) this serves two purposes for the teaching and learning of science. The first is that it shows a phenomenon can be reliably reproduced so that students could learn at first hand from the phenomenon instead of it being described to them and they trying to visualise it. Secondly, since phenomenon is not easy to reproduce, the outcome of a practical activity is evidence that students have carried out the activity correctly and with sufficient care and skill. Students are able to learn new ideas by being shown examples of them, rather than being given formal definitions, or other verbal accounts. As pointed by Millar (1998), "when we get pupils to investigate the relationship between force and acceleration for a trolley, for instance, we are showing what the scientific ideas of 'force' and of 'acceleration' mean, by giving concrete examples of them" (p. 29). Essentially then, according to Millar (1998) whatever teachers may say about why they conduct practical work, the real purposes of practical work done in schools is to try to

> "encourage students to make links between things they can see and handle, and ideas they may entertain which might account for their observation ... Practical work that is intended to support the teaching and

learning of scientific knowledge has to be understood, and judged, as a communicating strategy, as a means of augmenting what can be achieved by word, picture and gesture" (p. 29, 30).

Science practical work may therefore involve: illustrations of a phenomenon; providing experiences or getting a feel for phenomenon by students; exercises or routines for students to follow; developing a particular skill or becoming used to a piece of equipment or instrument.

Other surveys conducted over the past thirty years into reasons why teachers do practical work and the type of practical activities they do are reported by Woolnough (1998). According to him, teachers ranked those aims related to developing practical skills and attitudes most highly and those related to discovering or elucidating theory much lower. Yet Woolnough has observed that the type of practical work teachers consistently say that they do most frequently are structured experiments linked to theory (practical work to elucidate theory).

Organisation of Science Practical Work

Presently, practical activities could be provided through the use of either the computer-assisted approach or conventional approach. Computer-assisted practical work relates to the use of sensors, interfaces and software to monitor and display data collected during practical science activities. The conventional approach includes the use of standard laboratories, science kits, teacher demonstrations, and field activities. Some science educators who advocate the use of the conventional approach to practical activities insist that science practical work should be laboratory based whilst others advocate for practical activity not necessarily based in laboratories. Those who insist on laboratory based practical work assert that emphasis on acquisition of laboratory skills may be especially important for improving students ability to design experiments to solve problems. All practical work organised must therefore be hands-on laboratory activities.

Over the years laboratory manuals have become the blueprint for such practical activities. Jenkins (1998) reports "many of the experiments in physics and chemistry conducted by grammar school pupils in the early years of the 20th century ...have been clearly derived from a standard format" (p. 42). Consequently practical teaching of science in school laboratories have been reduced to what Jenkins describes as "a set of routine 'cook-book' exercises, sometimes involving little more than a lengthy elaboration of the obvious" (p. 42). Some science teachers in the past have organised science practical activities to emphasise the spirit of scientific curiosity by presenting experiments in the form of problems which students were required to solve.

Another way of organising science practical activities contained in the literature is by allowing students to use the science laboratory to conduct their own investigations to find out things for themselves. Apart from using laboratory based practical work to solve problems, von Secker and Lissitz (1999) think that laboratory based practical activities promote the development of process skills.

They therefore argue against the use of teacher demonstrations as well as large group instruction as a way of facilitating the development of process skills. In fact, Tamir and Lunetta (1981) think that laboratory based practical activity covers more areas of competencies when they emphatically stated that the main purpose of the laboratory is to afford experiences and challenges for students to solve problems, construct relevant science knowledge, undertake scientific investigations, promote inquiry and verify known scientific concepts and laws. However, in countries, which have severe resource shortages, practical activity in a conventional laboratory environment is generally unsustainable (Ross & Lewin, 1992). Practical work is therefore organised in the form of less fancied teacher demonstrations or large group experiments. The development of process skills by students through the use of these methods is however, very limited and may even be insignificant.

Computer-assisted practical work relates to the use of sensors, interfaces and software to monitor and display data collected during science practical activities. This is referred to in Britain as 'data logging' and in America as microcomputer-based laboratory according to Barton (1998). Software tools enable data collected to be investigated, manipulated, and analysed. As explained by Barton "these software tools provide the option for a new kind of practical science activity where pupils start by collecting data but spend most of the time considering the significance of the data by exploring it" (p. 248). Computed-based practical work is however, an innovation in practical work whose potential, as yet is largely untapped.

Use of Group Work in the Science Laboratory

According to Lazarowitz, Hertz- Lazarowitz & Baird (1994), experiments in the science laboratory have always required students to work in groups of two or four, due to the constraints of experimental processes and limited equipment and supplies. Anecdotal evidence shows that group work during science practical work is a common feature in Ghanaian SSS. Even though in some cases group work is resorted to as a result of constraints as mentioned, it is expected that when students work in groups during practical work, it will enable them to specify goals more precisely, plan procedures, generate and select alternatives, and review or modify their plans. Cohen, and Arechevela-Vargas as cited in Cohen (1994) have defined a group task "as a task that requires resources (information, knowledge, heuristic problem-solving strategies, materials, and skills) that no single individual possesses so that no single individual is likely to solve the problem or accomplish the task objectives without at least some input from others" (p. 8). However, it has been observed by Lazarowitz et. al. (1994) that most practical activities given to students are not inherently group tasks, since individuals could carry out the tasks. One may give a group a task, but, unless there is some reason for the group to interact, students may well tackle the task as individual work. This is especially the case if each individual must turn out some kind of worksheet or report. Lack of group work may also arise if the instructor divides the labour so that each person in the group does a different part of the task; the group has only to draw these pieces together in sequential fashion as a final product. The consequence is that there is comparatively little interaction, and students do not gain the benefits of using one another as resources, nor is there any basis for expecting the pro-social outcomes of cooperation (Cohen, 1994). Slavin (1983) is particularly critical about giving a group a single task that could conceivably be done by one person. If one person can accomplish a task there is little motivation on the part of members in a group to expend their effort in helping with the task. Therefore not all tasks assigned to cooperative groups are true group tasks.

Even though studies have shown that the number of participants in a group affects group discussion modes and individual learning, "there is lack of consensus in the peer interaction literature about the optimal size of groups" (Alexopoulou & Driver, 1996, p. 1100). Some studies suggest that pairs function better, others argue for larger groupings (e.g., four), "which give students the opportunity to consider a wider range of ideas, hence reducing the possibility of a discussion dying out too soon" (Alexopoulou & Driver, 1996, p. 1100). Theoretically, small groups offer special opportunities for active learning and substantive conversation and have been widely recommended as a means to achieve equity (Nystrand, 1986; Oakes & Lipton, 1990).

In science practical work, perhaps the main type of interaction desired is for students to offer each other assistance. Here the motivation for students to do so as well as the preparation for constructive assistance of one another becomes important factors. Cooperation is therefore needed from each member of the group. Cooperative learning methods generally involve heterogeneous groups working together on tasks that are deliberately structured to provide specific assignments and individual contributions from each group member. Cooperative learning should therefore not be confused with small groups that teachers often compose for the purposes of carrying out science practical activities because of limited number of apparatus. It is expected that students will have "cognitive as well as social benefits as they clarify their own understanding and share their insights and ideas with each other as they interact within the group" (Lazarowitz, Hetz-Lazarowitz, & Baird, 1994, p. 1122) during the course of the practical activity. Peers' modes of interaction on the social level therefore play an important part in the process of the construction of knowledge in group settings. Whether students want to work together seems to be of fundamental importance in any group activity. Thus, at least for the purposes of interactions during practical work, this may suggest that there could be advantages in using self-selected groups (Alexopoulou & Driver, 1996).

When students work in groups, cooperating with each other, they are likely to have a "more supportive climate for learning and in increased student ability to organise projects, divide and assign the work given to them, and take responsibility for completing it" (Lazarowitz, Hetz-Lazarowitz, & Baird, 1994, p. 1123). According to Lazarowitz et. al. (1994), "studies have consistently reported that on-task behaviour is higher when students learn through cooperative methods as opposed to individualized learning modes" (p. 1123). However, some researchers have also found that even though cooperative learning is desirable, it does not always result in greater understanding or enjoyment of subject matter (Sherman, 1988; Tingle & Good, 1990).

The Science Resource Centre Model

In spite of all the arguments against practical work, there seems to be no substitute for experiencing science at first hand as this assists in developing an understanding of scientific phenomena (Barton, 1998). Barton admits "practical work has the potential to challenge pupils' ideas and to draw them into learning about science" (p. 240). In line with this thinking, the MOE and WAEC have put emphasis on practical work in the teaching and learning of science through the use of laboratories. The WAEC chemistry syllabus for example, mentions the availability of well-equipped laboratories as a pre-requisite for schools pursuing chemistry courses at the SSS level. Unfortunately, in Ghanaian senior secondary schools (SSS) there are significant inequities in opportunities for access to laboratory experiences due to inadequate facilities and equipment, and lack of money to purchase consumables. Students in less-endowed schools may therefore be at a disadvantage when it comes to practical work.

To address issues surrounding inequitable opportunities for effective science course (which involves practical work), a policy option taken by the MOE was to create special centres called Science Resource Centres (SRC) stocked with adequate resources and sited in selected SSS. These SRCs act as satellite centres, which serve surrounding SSS that lack the needed resources. Documents available from the office of the National Co-ordinator for SRCs indicate that presently the centres are based in 107 selected SSS in Ghana and service schools in their locality. These centres have been equipped with basic science equipment including modern electronic devices and computers to be used in the teaching and learning of science. Buses have been provided to all SRCs for use by satellite schools. Schools are required to pay user fees (which are charged to students) before they are allowed to use the centres. The centres' own teachers teach all students who go there. The project is a collaborative effort between the Government of Ghana (GOG) and Philip Harris International of Britain with the GOG providing the funds whilst Philip Harris International provides the equipment and technical expertise. Under the agreement, the GOG rehabilitated and refurbished old laboratories in selected schools whilst Philip Harris International supplied and installed science equipment at those centres. The objectives of the SRCs at the District level include the following:

(i) to serve as teaching centres to supplement existing facilities in secondary schools and give ample opportunities for practical work using modern facilities and techniques including the use of computers

(ii) to provide additional tuition facilities for students in schools without well-equipped laboratories

(iv) to expose students and teachers to the use of computers and other electronic equipment in the teaching of science

Source: Status Report of the Science Resource Centres Project,

1997, p 2.

According to the Status Report of the Science Resource Centres Project published in 1997 the intended benefits of this project include:

(i) improvement in the teaching/learning methodology

(ii) increased enthusiasm of students in the learning of science

(iv) teachers and students being computer literate and therefore better prepared to fit into the modern information technology age.

Source: Status Report of the Science Resource Centres Project,

April 1997, p. 2.

It is evident that practical activities have high costs compared to classroom based teaching in terms of equipment and time (Ross & Lewin, 1992). The MOE has committed about 20 million pounds sterling to the establishment of SRCs with the objective of supplementing existing facilities in SSS to provide equal opportunities to students to enable them engage in practical work and to provide tuition for students in schools without the necessary laboratory facilities. In 1998, the GES Council requested the National Co-ordinator of the SRCs to undertake a small-scale assessment of the SRC project. A total of 399 respondents made up of 63 teachers and 336 students were purposively selected from a few SSS in Ghana. The findings of the survey revealed that most satellite schools visited the SRCs once in every two weeks. This means that the average attendance per term at the centres by satellite schools was five times. Almost all the host schools however, used the centres at least once a week thus giving them some advantage in terms of access. Even though the majority of students stated that they enjoyed going to the centres mainly because of the modern equipment there, the minority stated reasons, which need to be fully investigated. For example, some of the students stated that they were not able to do the required number of practical activities planned for them since they only went to the centre once every two weeks. Others stated that they did not get access to some of the equipment, for instance, the computer. Some students also indicated that sometimes they did not understand the practical activities they undertook at the centre. Given the above problems and constraints, it was not surprising that some students emphatically stated that they did not enjoy going to the SRCs.

These findings though limited in scope raise questions about the benefits that students (particularly those from satellite schools) may be deriving from the SRCs. It also casts doubts on whether the SRCs are really having the desired impact in terms of promoting equity among students with respect to practical activities and providing tuition for students in schools without well-equipped laboratories. It would be desirable therefore to investigate these issues in order to help inform government policy on the provision of very expensive laboratory equipment and materials for the teaching and learning of science at the SSS level.

Attitude of Students towards Science Practical Work

Historically, research on science education has focused primarily on cognitive educational outcomes. However, research into the affective domain has now become a major focus in science education, and one of the key variables within the affective domain that has drawn attention is attitude (Weinburgh, 1995). Ajzen (1989) proposed a theory of planned behaviour in which behavioural goals could be predicted from attitudes (Weinburgh, 1995). Since then, "many researchers have examined attitudes by studying variables that influence it" (Weinburgh, 1995, p.388).

Definition of Attitude

The term attitude conveys different meanings in the science education literature. In 1929, Thurstone defined attitude as "the sum total of a man's inclinations and feelings, prejudice and bias, preconceived notions, ideas, fears, threats and convictions about a specific topic" (as cited in Abdalla, 1991, p. 96). Others have defined attitude as the affect for or against a psychological object. Various definitions of attitude can be restated in any of the following ways:

(a) affect for or against

(b) evaluation of

(c) like or dislike

(d) positiveness or negativeness toward a psychological object

The characteristics of attitude as summarized by Goldstein cited in Abdalla

(1991) are as follows:

(a) Attitudes are learned

(b) Attitudes predict behaviour

(c) The social influences of others affect attitudes

(d) Attitudes are evaluative, emotion is involved.

The meaning of attitude focused on in this review of the literature centres on affective reactions to science practical work. Attitude in this context implies interest, enthusiasm, satisfaction, enjoyment, feelings of like and dislike. According to Katz and Stotland cited in Akinmade (1992), attitudes have three components, namely; affective, cognitive, and behavioural. The characteristics of the three components are as follows:

> the affective aspect is reflected in the expression of likes and dislikes, pleasant and unpleasant states towards an object. The cognitive aspect represents knowledge of the identity of the object, while the behavioural part is the actual movement towards or away from the attitude object (p. 76).

The term "attitude towards science practical" is therefore used to indicate all that an individual feels and thinks about science practical work as a result of interacting directly or indirectly with various aspects of science practical activities and which exert a direct influence on his/her behaviour towards science practical work. Given that attitude has three dimensions, Schibeci (1983), has argued that attitude towards science is predominantly affective and this is affected by many variables (Freedman, 1997). One such variable is hands-on activity-based laboratory instruction, which appears to have a consistent positive influence on students' attitude toward science (Freedman, 1997). According to Freedman "the laboratory, as a factor in the learning environment, is intrinsic in the development of positive student attitudes toward science" (p. 344). Attitude towards science is seen "as a learning outcome of the laboratory experience within the science curriculum" (Freedman, 1997, p. 344). In this sense, students' attitude towards laboratory work is taken for granted. Thus even though the laboratory is seen only as an intrinsic factor in the attitude toward science, it could as well be an extrinsic factor. Hence laboratory based science practical work could be seen as an attitude object. This makes the study of students' attitude towards science laboratory work desirable, as research on attitudes in science education has primarily focused on attitudes towards science and not on science practical work.

Measurement of Attitude

Although attitudes are not easy to measure, attempts to measure attitudes have been more successful than attempts to define them (Abdalla, 1991). As noted by the sociologist Thurstone, cited in Freedman (1997) "attitude is complex and not describable by any one numerical index" (p. 344).

The concept of attitude, like many abstract concepts, is a construct. It is an instrument that serves the human need to see order and consistency in what people say, think or do. However, it is not something that can be examined, or measured in the same way one can examine the cells of a person's skin

(Abdalla, 1991). We can only infer that a person has attitudes by his words or actions. As stated above, although attitudes are not easy to measure, attempts to measure attitudes have been more successful than attempts to define them. When there is no reason for someone to hide anything, then it is assumed that one's statements about one's own attitudes may be accepted as the best indicator of the attitude. Responses to statements are used to measure attitudes. The most popular being the Likert scale.

Students' Psychosocial Perception of their Science Laboratory Environment

In the past, research involving science students' outcomes focused primarily on educational objectives in the cognitive domain. In more recent times however, attention has been paid to outcomes in the affective domain and the study of students' perceptions of their learning environment has formed a primary component of this research (Weinburgh, 1995). Classroom and school environment factors have been found to be particularly important influences on students' outcomes, even when a number of factors were controlled (Henderson, Fisher & Fraser, 1998). Within the learning environment, students' perceptions are influenced by psychological and social factors. Hence studies into students' perception of their learning environments have focused on psychosocial factors.

Research into psychological and social factors, which make up the learning environment, has developed over the past 20 to 30 years. This period has also witnessed the emergence of a strong tradition of studying classroom climate through the perceptions of students and teachers (Fraser & Walberg, 1991).

The study of classroom environments started when Rudolf Moss developed a social climate survey for use in his work in psychiatric hospitals and other human environments. From this work, he developed the Classroom Environment Scale (Raaflaub & Fraser, 2002). Moss identified three general categories of dimensions necessary for conceptualising all human environments. These general categories are:

> Relationship Dimensions (the nature and intensity of personal relationships), Personal Development Dimensions (basic directions along which personal growth and self-enhancement tend to occur), and System Maintenance and System Change Dimensions (extent to which the environment is orderly, clear in expectation, maintains control, and is responsive to change).
>
> (Fraser, McRobbie & Giddings, 1993, p. 4)

All three general dimensions must be assessed to "provide an adequate and reasonably complete picture of any environment" (Fraser, McRobbie & Giddings (1993, p. 4).

Interest in the study of learning environments became more prominent when there was evidence that learning outcomes and student attitudes towards learning were closely linked to the environment in which the learning took place (Myint & Goh, 2001). Tel (1991) has noted that perceptions importantly influence human behaviour in science related issues and this has been found to exist in almost all countries of the world. International research efforts involving the conceptualisation, assessment, and investigation of perceptions of aspects of the classroom environment have now firmly established the classroom environment as a thriving field of study (Henderson, Fisher & Fraser, 1998). In the past three decades therefore, much attention has been given to the development and use of instruments to assess the quality of science classroom learning environments from the perspective of students, teachers and external observers (Fraser, 1994; Fraser & Walberg, 1991). Some past studies have examined associations between students' attitudinal outcomes and student perceptions of the learning environment in science classes. Past classroom environment research have used a variety of questionnaires such as the "Learning Environment Inventory", "Classroom Environment Scale", "Individualised Classroom Environment Questionnaire", "Science Laboratory Environment Inventory", "Constructivist Learning Environment Survey", "My Science Class Inventory" (Chin & Wong, 2001; Fraser, McRobbie & Giddings, 1993; Taylor, Fraser & Fisher, 1997) among others to study learning environments. With the emergence and availability of a whole range of psychosocial environment questionnaires for use in different schools and classroom contexts, the study of learning environments has come to assume a position of significance.

Classroom environment instruments have been used as sources of predictor and criterion variables in a variety of research studies conducted in elementary and secondary schools. The most common means of measuring the learning environment has been through the use of perceptions of participants. According to Raaflaub and Fraser (2002), this has proven useful as it provides valuable information through the eyes of students or teachers as opposed to external observers.

Even though there have been a lot of science education researches over the last quarter of a century on classroom learning environments, Hegarty-Hazel (1990) has noted that, surprisingly, hardly any of this work focused specifically on science laboratory classes, which constitute one of the most important environments in science teaching. It was not until 1992 that Fraser, Giddings and McRobbie developed an instrument called the Science Laboratory Environment Inventory (SLEI) for the study of science laboratory environments at the secondary school level. Research has not been comprehensive about science laboratory environments and so enough is not really known about the effects of laboratory instruction upon students learning and attitudes (Fraser, McRobbie & Giddings, 1993). There are therefore very few studies on students' perception of science laboratory environments. It is therefore not surprising that research into psychosocial science laboratory environment, which has become one crucial dimension of science education, has not yet been explored in Ghana.

In a study on "Pupils' classroom environment, perceptions, attitudes and achievement in science at the upper primary level" in Singapore, Chin and Wong (2001) have reported that pupils surveyed indicated they wanted a much better material environment for the study of science. They concluded in their study that as learning of science was often enhanced through hands-on experiments and experience, a conducive and well-equipped environment was likely to have influence on the learning of science. The results of their study showed that four environment dimensions (difficulty, cohesiveness, integration and material environment) have significant associations ($p<.05$) with attitude scores. The strong positive correlation found by Chin and Wong between pupils' perception of the material environment and attitude also reiterate the importance of the material environment in the learning of science. Also science laboratory classes that integrate knowledge learnt from science lessons and provide conducive material environment may ultimately have a positive impact on how pupils' learn, and their attitude towards science. The significant environment-attitude association for the integration scale concurred with past research by Wong and Fraser (1996).

In another study in Tasmania (Australia), Henderson, Fisher and Fraser (1998), measured students' perception of some aspects of their learning environment in environmental science classrooms using the Environmental Science Learning Environment Inventory (ESLEI). They found that students studying more than one science subject perceived significantly higher levels of Student Cohesion and a more favourable material environment than their counterparts studying only one science subject. They also investigated associations between students' perceptions of their classroom learning environment and students' attitudinal outcomes. Of the five aspects of learning environments measured in their study, student cohesion, involvement, and task orientation were found to be most strongly associated with positive attitudinal outcomes.

Fraser, McRobbie and Giddings (1993) explored the degree of association between students' attitudes and their perceptions using the Science Laboratory Environment Inventory (SLEI) they had developed and cross validated. Five dimensions were found to account for the psychosocial perception of students' laboratory environments. These were students' cohesiveness, open-endedness, integration, rule clarity and material environment. They reported that overall, these dimensions were found to be positively related with student attitudes with the exception of open-endedness, which was negatively related to attitudes for some subsamples. In particular, more favourable student attitudes toward laboratory work were found in classes perceived to be higher in student cohesiveness and integration. For example, with the class mean as the unit of analysis, simple correlation between attitudes and integration was in excess of 0.6 for the total sample (Fraser, McRobbie & Giddings, 1993). However, as rightly noted by Chin and Wong (2001), it must be pointed out that it cannot be concluded in absolute terms that the nature of the environment caused the observed student attitudinal outcome.

Implication of Literature Review for this Study

The literature that has been reviewed has shown that there is agreement among some science teachers on the use of science practical activities in the teaching and learning of science worldwide. However, what seems to differ among science teachers is how science teachers perceive the purposes of science practical activities in the teaching and learning of science. Even though the organisation of science practical activities in Ghanaian SSS has been taken for granted, as it is examined every year by the WAEC, what has not been investigated are teachers views on the purposes of science practical activities, and students' perceptions of and attitude towards these activities. However, teachers' and students' views about science practical work could affect how science practical activities are conducted, the emphasis put on them, and how they are organised. Given the reported weaknesses of SSS science students in science practical examinations as contained in the reports of WAEC Chief Examiners, there is an urgent need to investigate science practical work in Ghanaian SSS in order to shed some light on how it relates to students' performance. It is to this problem that the present study is addressed.

CHAPTER 3

METHODOLOGY

Introduction

The purpose of this chapter is to provide a detailed description of the design, instruments and procedure used to gain insights into science practical activities in Ghanaian SSS. To be able to achieve this, the study used a two-phase design.

Research Design

Description of Research Design

This study was in two parts, and followed a mixed method design using both quantitative and qualitative techniques (Creswell, 1994; Hogan, 1999). A comparative quantitative design was used to test hypotheses on science students' attitude towards science practical activities and perception of their psychosocial laboratory environment in SRC and satellite schools. A hypothesised relationship between students' attitude and perception was also tested. To accomplish this, a survey method was used with science students randomly selected from five SRC and four satellite schools. All sampled students completed two sets of questionnaires; one on perception of their psychosocial laboratory environment and the other on their attitude to science practical work. The individual students' scores were used as the unit of analysis. The survey also covered science teachers' views on the role of science practical activities in the teaching and learning of science and how they are organised. This part covered a period of three months from April to June 2002.

In the second part of the study, a sub-sample of four schools (two SRC and two satellite) were purposively selected from the original sample for more intense study. These case studies included observation of students' science practical notebooks in biology, chemistry and physics. This was followed by interviews with focus group of students, and individual Heads of Departments (HODs) and Science Resource Centre (SRC) Co-ordinators. The purpose of these was to investigate, qualitatively questions that emerged in the first part of the study. The qualitative portion of the study included analyses of the discussions of the focus groups of students with whole groups as the unit of analysis. The qualitative data provided insights and triangulation for interpreting the quantitative results.

Rationale for the Design

Even though research into educational issues has its own individual focus, it cannot divorce itself from quantitative and qualitative methodological issues that social science research raises. There has been a virtual catalogue of arguments for engaging in research of one form or the other as the assumptions underlying quantitative (traditional, positivist, empiricist etc.) and qualitative (naturalistic, interpretive etc) paradigms are diametrically opposed to each other. The point here however, is not to rehearse the debates on the merits and demerits of the two opposing paradigms.

Burgess, cited in Akwesi (1994) has posed two questions, which in his view should constitute the basis for choosing one method or the other. These are "What kinds of information are relevant?" and "What kinds of methods are relevant for the particular topic under investigation?" (p. 167). Burgess' contention is that there is no best method in educational research and that the method one uses should be suited to the issue or topic being explored. Also, Vulliamy, Stephens and Lewin (1990) have pointed out that the approach to social research does not stem from fundamental philosophical commitments only. Other significant considerations such as the particular purposes of the research and the practicality of various strategies given the circumstances in which the inquiry is to be carried out must not be overlooked.

This study, first of all, sought to investigate factors underlying students' poor performance in science practical work in Ghanaian SSS. To be able to do this, there was the need to provide descriptive and inferential information on students' perception of their psychosocial laboratory environments; their attitudes to science practical work; teachers' views on the essential functions of science practical work and how it is organised. This called for the gathering of standardized information by using the same instruments and questions for all participants.

Secondly, the study sought to find out whether there is any relationship between students' attitudes to science practical work and their perception of science laboratory environment. To be able to do this, it was necessary to gather data from a wide population of science students in order to make generalizations about the perceptions and attitudes of students to science practical work in satellite and SRC schools. To meet these expectations, the survey method was found most appropriate for use.

Instead of defending the patterns that would emerge from the survey by appealing to the general case based on judgement derived from a wide experience with no systematic empirical grounding, it was decided that the patterns should be empirically validated. To do this, the researcher employed qualitative design using semi-structured interviews. This enabled the researcher to gain further understandings into the factors and variables being investigated, thereby increasing the validity of the research findings. Two satellite and two SRC schools were selected as case study schools. As noted by some researchers (Gall, Borg & Gall, 1996; Hopkins & Antes, 1990; Merriam, 1988), one of the advantages in doing a case study lies in the fact that it allows for the study of all the elements present in the setting in which the inquiry takes place, and the collection of very extensive data in order to produce an in-depth understanding of the phenomenon being studied. In other words, case studies observe effects in real contexts. Since contexts are unique and dynamic, case studies could be used to "investigate and report the complex, dynamic and unfolding interactions of events, human relationships and other factors in a unique instance" (Cohen, Manion & Morrison, 2000, p 181), which quantitative data may fail to achieve.

Herriot and Firestone cited in Yin (1994) have argued that, a multiple-case design has a distinct advantage over a single case design. According to them, the evidence from multiple cases is often considered more compelling, and hence the overall study is therefore regarded as being more robust.

It was evident that both quantitative and qualitative methodologies were appropriate and necessary for this study in view of the nature of the research questions posed and the issues that required exploring. The use of mixed methodologies made it possible to get detailed, in-depth information in order to describe, interpret and make informed judgment concerning teachers' views on the essential functions and organisation of science practical activities in schools and how this influence attitudes and perceptions of students about science practical work. Also the use of qualitative research strategy in a broad framework of a quantitative methodology was aimed at gathering further data from a smaller sample, in addition to data collected using measurement-oriented items.

This study therefore employed a combination of two basic methodologies (qualitative and quantitative) and two basic methods (surveys and in-depth interviews) for data collection. The two methods of different methodological origin and nature were used to

a) obtain a variety of information on practical activities in Ghanaian SSS
b) achieve a higher degree of validity and reliability of data
c) overcome the deficiencies of single method studies

There is however, a major pitfall in the use of case study designs. The subjectivity of respondents, their opinions, attitudes and perspectives together contribute to a degree of bias. According to Vulliamy, Stephens and Lewin (1990) because of lack of rigour in the collection of qualitative data it is easy for biased views to colour the findings and conclusions. Others have written about the difficulty of establishing reliability and validity. To minimise these shortcomings, multiple sources of evidence were used in this study, which provided multiple measures of the same phenomenon in each case study school. In this way the data in these multi-site case studies could be used to compare and confirm the data (Guba & Lincoln, 1985).

Despite the obvious advantages of integrating quantitative and qualitative data by the use of complementary methodologies, the two methodologies are based on different assumptions. It is therefore possible that such different research techniques could produce different results. This is a weakness in the use of this design.

Population

The Central Region had 49 SSS, with 18 of them offering all three elective science subjects in the 2001/2002 academic year. Of the 18 schools, 11 were SRC schools with the remaining seven constituting satellite schools. The schools categorized as SRC schools were locations, which hosted the SRCs. The satellite schools were schools which went to the SRCs for some of their science practical activities. The target population for this study is all SSS3 students in satellite and SRC schools offering all three elective science subjects (physics, chemistry and biology) in the Central Region of Ghana in the 2001/2002 academic year.

Sampling

The schools were thus in two clusters of SRC and satellite schools. Each school was assigned an identification number and proportionate simple random sampling was used to select four satellite schools and five SRC schools yielding a total of nine schools. These were made up of two boys' schools, one girls' school and six mixed schools.

A table for estimating the sample size from a given population developed by Krejcie and Morgan cited in Cohen, Lawrence and Morrison (2000) (Appendix B) was used to determine the student sample sizes in each school. In each school, students were selected through simple random sampling by class using the sample sizes developed by Krejcie and Morgan. This yielded a total of 184 students from SRC schools and 204 students from satellite schools making a total of 388 students. In each school (SRC and satellite) all elective science teachers at post at the time of the research numbering 50 formed the sample of teachers for the study.

Four case-study schools were purposively selected from the main survey sample to gain further insights into students' perceptions and attitudes, and teachers views about science practical activities that emerged from the survey. Factors such as proximity, time and financial constraints influenced the choice of schools. In each of the four schools, four to six science students (depending on the number of streams in the school) were selected for focus

Instruments

The instruments developed for the study were:

(1) Attitude towards science practical (ASP)

(2) Science laboratory environment questionnaire (SLEQ)

(3) Questionnaire on the role of science practical work (QRSP)

(4) Questionnaire on the organisation of science practical work (QOSP)

(5) Interview protocol for students (IPS)

(6) Interview protocol for heads of science departments (IPHOD)

(7) Interview protocol for SRC co-ordinators (IPSC)

Attitude towards Science Practical (ASP) Instrument

In order to develop this instrument for assessing students' attitude towards science practical activities, the researcher drew on traditions of past ASPs by (e.g., Abdalla, 1991; Misiti, Shringley & Hanson, 1991; Orion & Hoftstein, 1991). The initial development of the new instrument, called the Attitude towards science practical (ASP), was guided by the following criteria:

1. Consistency with the literature on attitude to science practical

   A review of the literature was undertaken for the purpose of identifying scales that are considered important in the attitude to science practical activities (Abdalla, 1991; Misiti, Shringley & Hanson, 1991; Orion & Hoftstein, 1991).

2. Salience to teachers and students

   By asking students to respond to an open-ended questionnaire on their attitude towards science practical activities and interviewing science teachers in two SSS in the Cape Coast Municipality enabled them to bring out what they considered to be the most important issues on the variables being investigated. Also science teachers and students in the two pilot schools were asked to comment on draft versions of the set of items in an attempt to ensure that teachers and students considered the ASP's individual items salient.

The development of a reliable and valid attitude measure is a process that consists of several distinct stages (Koballa, 1984). The main stages in the development of the ASP were:

a) conceptualisation – the attitude scales of practical work
b) item formulation
c) content validation
d) construct validation -statistical analysis and comparison with experts' judgement

Stage 1: Conceptualisation

The first stage in the development of the instrument was to identify the various scales of students' attitude towards science practical work. It was hypothesized by the researcher that attitude to science practical work does not consist of only one scale but rather several distinct scales. On the basis of the researcher's personal experience with students during practical work, the researcher hypothesised that students' attitude towards science practical work would have the following scales:

(a) Practical work as a learning tool

This aspect concerns the various components of students' views of practical work as a learning tool; e.g., understanding of concepts taught in a theory class through practical activities; practical activities as a tool for the acquisition of scientific skills etc.

(b) Frustration

Doing science experiments is sometimes frustrating when experiments do not go as expected. This could be due to faulty apparatus, lack of understanding of the practical, and lack or inadequacy of the necessary apparatus. These could affect the attitudes of students to practical work.

(c) Interest

Generally one would expect students to show considerable interest when asked to go for science practical activities, as this involves either a change of environment or activity or both and serves as a break from theory lessons.

(d) Group Work

Sometimes students work in groups during practical activities. Group work may foster co-operation between students, which may facilitate the performance and understanding of practical work. Group work may therefore be a factor in considering students' attitude to science practical activities.

(e) Write-up

Performing an experiment is one thing, and writing it up is another. Students face may difficulties trying to reconcile experimental results with what is accepted theoretically. Students may also have difficulties with the drawing of graphs or solving problems that go with practical activities. These issues may influence students' attitude towards science practical activities.

Stage 2: Item Formulation

It was necessary to collect items that would make up a scale, which could be understood easily by students at the SSS level. Some of the items collected were adapted from instruments used to measure attitudes towards science practical work by other researchers such as Abdalla (1991), Misiti, Shringley and Hanson (1991), and Orion and Hoftstein (1991). Thirty students in one of the SSS in the Cape Coast Municipality were asked to respond to the following open-ended items:

1. What I like about science practical activities are ...
2. What I don't like about science practical are...

Some of the statements made by the students were reworded and added to the pool of items. The idea was to collect a lot of items related to each of the five scales identified. The items collected were reworded to suit both the object of attitude towards science practical activities and the respondents. While writing the statements, the criteria used by Edwards (as cited in

Abdalla, 1991, p. 132) were taken into consideration. The criteria are as follows:

1. Avoid statements that:
   (a) refer to the past rather than to the present;
   (b) are irrelevant to the psychological object under consideration;
   (c) may be interpreted in more than one way;
   (d) are likely to be endorsed by almost everyone or almost no one.
2. Select statements that:
   (a) are believed to cover the entire range of the effective scale of interest;
   (b) are short, rarely exceeding 20 words;
   (c) contain only one complete thought.
3. Keep the language of the statement simple.
4. Keep the language of the statement clear.
5. Keep the language of the statement direct.
6. Exercise care and moderation in the use of words such as "only", "just", "merely", and others of similar nature.
7. Use simpler rather than compound or complex sentences.
8. Avoid words that may not be understood by the respondents.

Thirty eight items were originally constructed to represent the five attitude scales. Each item was scored on a five-point Likert –type scale (5-strongly agree, 4-agree, 3-undecided, 2- disagree, 1-strongly disagree). The higher the scale score, the more a student would demonstrate that particular scale of attitude.

Stage 3: Content Validation

At this stage, five science teachers from the two pilot schools in the Cape Coast Municipality and two science educators from the University of Cape Coast were asked to validate the content of the questionnaire. They were given the items and the identified scales and asked to group the items according to the scales indicated, and to assess the quality of each item, in the context of clarity, ambiguity, generality, etc. The science teachers and science educators first worked individually and met to resolve all discrepancies in their evaluation of the items.

The science teachers and science educators agreed on 25 items and their scales. The remaining 13 items were abandoned either because they did not satisfy the quality criteria or because science teachers and science educators disagreed about the scale to which the item(s) belonged.

The ASP was pilot tested using a total sample of 336 SSS3 elective science students in two SSS in the Cape Coast Municipality by simple random sampling by class from a population of 502 students. The sample had a mean of 17.0 years and a standard deviation of 0.50 years and was made up of 152 students from satellite and 184 students from SRC schools. The questionnaires were distributed to the students in their science laboratories by the researcher. Students in the presence of the researcher completed the questionnaires. The questionnaires were then collected and analysed.

Item Analyses

The first step in refining and validating the ASP involved a series of item analyses procedures using Statistical Package for Social Sciences (SPSS). Data were subjected to item analyses in order to identify items whose removal would enhance the internal consistency of the instrument. In particular, an attempt was made to improve the internal consistency by removing items with low item remainder correlations (i.e. correlations between a certain item and the rest of the items excluding that item). All items that reduced the alpha value were deleted. These item analyses procedures led to the deletion of 9 (1, 4, 7, 10, 14, 17, 20, 21, 23) of the 25 items to produce 16 items. After these nine items had been dropped from the ASP, the Cronbach alpha reliability coefficient increased from 0.72 to 0.88. The items deleted included all the items under frustration, one item from Interest and three items from Write up scales.

There were very low neutral responses (neutral percentages ranged from 0.3% to 1.8%), which suggests evaluative quality (that favourable-unfavourable feeling toward an object or idea) of the instrument. Also the distributions of data generated by items on this instrument are distributed across Likert's continuum again suggesting evaluative quality. This 16-item version with an alpha Cronbach coefficient of 0.88 formed the starting point for the series of factor analyses described in the next section.

Factor Analyses

The second major stage in the refinement and validation of the ASP involved a series of factor analyses using SPSS. The purpose was to examine further the internal structure of the set of 16 items, which had survived item analyses. The 16 items from the ASP were therefore analysed using principal axis factor analysis with varimax rotation.

Factor analysis gave three factors with eigenvalues greater than one to be rotated. Three criteria were used to determine the number of factors to rotate: the scree test, number of eigenvalues greater than one, and the interpretability of the factor solution. The scree plot shown in Figure 1 confirmed that the ASP consisted of more than one linear scale. The ASP was therefore, made up of more than one scale. Even though the scree plot strongly suggests a final solution with two principal components, no proper interpretation could be given to the components after rotation. Consequently three factors with eigenvalues greater one were rotated using a varimax rotation procedure. The result of the rotated solution as shown in Table 2 yielded the following three interpretable factors: learning tool, interest and equipment. Items 13 and 18 seem to be strange measures of factor 1 and were therefore deleted. With the deletion of the 2 items from the ASP, the 14-item, three-factor solution shown in Table 2 was decided upon as the optimal structure for the final version of the ASP.

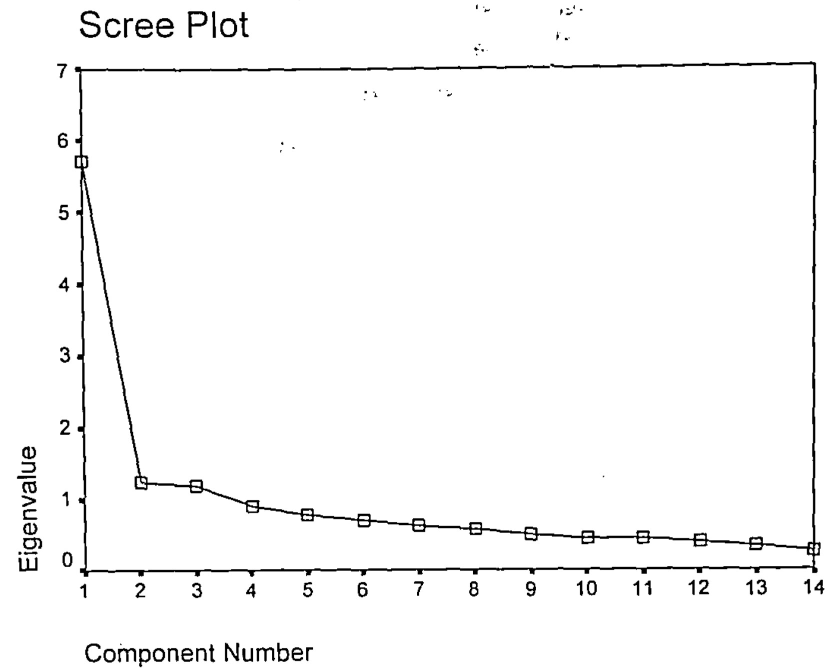

Figure 1. Scree plot of eigenvalues of ASP

Each of the remaining items had a factor loadings greater than 0.40, higher than the conventionally accepted value of 0.30 for analysis involving individual students as the unit of analysis (Fraser, McRobbie, & Giddings, 1993). The percentage of the total variance of 49.2% explained by the three factors is quite large according to Fraser, McRobbie & Giddings (1993) given that individual means was used as the unit of analysis. The structure of the eigenvalues shows a dominant first principal component. The amount of variance between respondents explained by the first factor is 34.6%. This means that science practical activities as a learning tool for the study of science concepts is a dominant factor influencing the attitude of students towards science practical work.

Table 2

Rotated component matrix showing factor loadings and amount of variance explained for the final ASP

	Factor		
Item Number	1	2	3
12	831		
19	765		
5	764		
25	726		
11	595		
16	573		
24		799	
15		751	
6		510	
22		498	
3		434	
2			772
9			730
8			683
% of explained Variance	34.6	8.6	7.0
Eigenvalue	6.23	1.54	1.26

Decimal points omitted for factor loadings.

Factor 1= learning tool, Factor 2= interest, Factor 3= equipment

This confirms the assertion by Woolnough (1998) that students like practical activities aimed at discovering or elucidating theory. The amount of variance explained by the second and third factors is only 8.6% and 7.0% respectively.

Table 2 shows that the factor loadings on the first component ranged from 0.57 to 0.83. This means that all respondents had very high and positive correlation with the first principal component. This component was interpreted as the extent to which science practical activities help in the learning of science and was named Learning tool. The second principal component had factor loadings ranging from 0.43 to 0.80. This was interpreted as the extent to which students are interested in science practical activities and the subsequent write-ups. The third principal component had factors ranging from 0.68 to 0.77 and was interpreted as the extent to which students like working with science equipment. This scale was named equipment. Thus three scales emerged in the pilot study for the final ASP. The scales and their interpretations are given in Table 3.

Table 4 presents alpha coefficients for the three attitude scales using the individual student as the unit of analysis.

Coefficients ranged from 0.67 to 0.87, exceeding the threshold of 0.60 given by Nunnally (cited in Henderson, Fisher and Fraser, 1998) as being acceptable reliability for research purposes. The overall Cronbach's alpha coefficient was 0.88. The final ASP is shown in Appendix C.

In summary, the pilot study identified three factors that underlie SSS students' attitude to science practical work. These are:

(a) learning tool

(b) equipment

(c) interest

Table 3

Scales and descriptions of the final ASP instrument

Scales	Description
Learning tool	Extent to which science practical activities help in the learning of science
Interest	Extent to which students are interested in science practical activities and write-ups
Equipment	Extent to which students like working with science equipment

Table 4

Internal consistency (Cronbach alpha coefficient) and variance of each the ASP scales

Scale	Alpha reliability
Learning tool	0.87
Interest	0.73
Equipment	0.67
Total	0.88

Learning tool was identified as the most prominent factor influencing the attitude of students towards science practical work as it accounted for over 40.0% of the total variance. A series of item and factor analyses led to the evolution of a refined version of the ASP, which was found to display satisfactory internal consistency, reliability and factorial validity using the individual as the unit of analysis.

Science Laboratory Learning Environment Questionnaire (SLEQ)

The SLEQ was developed to measure students' psychosocial perception of their science laboratory environments in Ghanaian SSS. In developing the SLEQ, the Science laboratory classroom environment Inventory developed by Fraser, McRobbie and Giddings, (1993) served as a guide. The instrument developed by Fraser et al (1993) was itself based on widely used questionnaires such as the Learning Environment Inventory, the Individualised Classroom Environment Questionnaire, and the Classroom Environment Scale. The development of the SLEQ was also guided by three criteria used by Fraser et al. (1993), which were also found to be relevant to this study.

The criteria are:

1. Coverage of Moss' general categories

Scales chosen provided coverage of the three general categories of scales identified by Moss for conceptualizing all human environments.

These general categories are

Relationship, Personal Development, and System Maintenance and System Change (Fraser, McRobbie & Giddings, 1993) According to Moss (cited in Fraser et al., 1993), at least all three general categories must be assessed to "provide an adequate and reasonably complete picture of any environment" (p. 4). The scales for the SLEQ were therefore chosen to include scales in each of Moos' three general categories.

2. Economy

In order to achieve economy in terms of the time needed for answering and scoring, the SLEQ was designed to have a relatively small number of reliable scales, each containing a fairly small number of items.

3. Salience to teachers and students

By interviewing numerous science teachers and students at the SSS level and by asking my supervisors and other colleagues to comment on draft versions of sets of items, an attempt was made to ensure that science educators, science teachers and students considered the SLEQ scales and individual items salient.

In developing the SLEQ, the researcher assumed that students' perception of their psychosocial science laboratory environment was multi-dimensional. Four scales that run through most of the learning environment instruments and which the researcher considered to be appropriate for the science laboratory environment questionnaire were material environment, supervision, open-endedness and integration. The researcher wrote 23 items to cover the four areas mentioned. These items formed the initial version of the SLEQ

As it was done in the case of the ASP, the SLEQ was also pilot tested with the same sample of students used for the ASP. The questionnaire was distributed to the students in their science laboratories by the researcher. Students in the presence of the researcher completed the questionnaires within 30 minutes. The questionnaires were then collected and analysed.

Factor Analyses

In refining and validating the SLEQ, a series of factor analysis were conducted using SPSS. The 23 items from the SLEQ were analysed using principal axis factor analysis. Factor analysis gave five factors with eigenvalues greater than one to be rotated. The scree plot which is the plot of the eigenvalues shown in Figure 2 confirmed that the SLEQ consisted of more than one linear scale and hence the assumption that more than one scale underlie students' perception of their psychosocial science laboratory environment was upheld. Even though the scree plot strongly suggests a final solution with three principal components, there were five eigenvalues greater than one. The rotation of these five components using varimax rotation and the resultant interpretations seemed more reasonable. Factor analysis led to the removal of five items (Items 4, 11, 14, 16 and 19) from the SLEQ. The reasons were that items 11 and 16 loaded significantly on more than one scale. Item 14 seemed to be a strange measure of and was therefore removed.

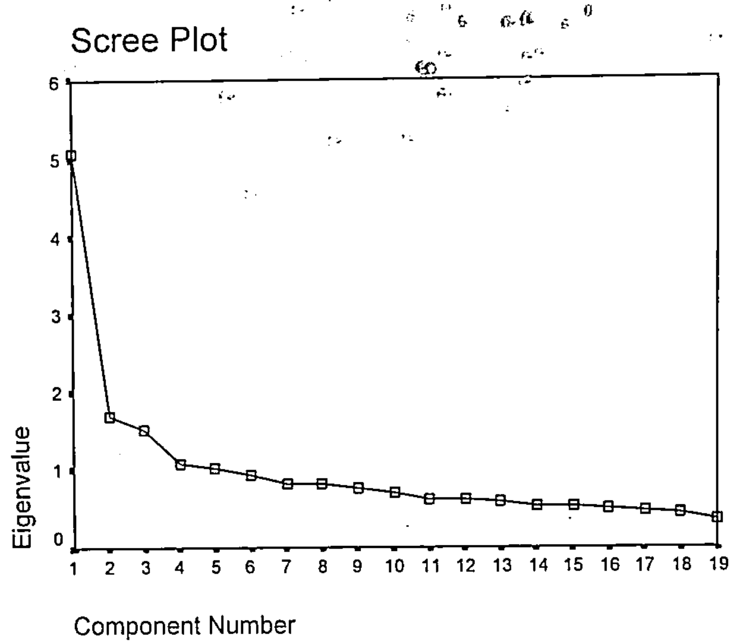

Figure 2. Scree plot of eigenvalues of SLEQ

Open-endedness did not emerge as a factor during the validation of the SLEQ as items 4 and 19 that belonged to that scale were deleted. This is not surprising, as many past studies have reported low level of open-endedness (Chin & Wong, 2001). The supervision scale seems to somewhat overlap with the orderliness scale and so there was very little differentiation between supervision and orderliness looking at the items that constituted the two scales. When factor and item analyses were conducted on the remaining items, four scales finally emerged and the material environment scale was split into two. Supervision and orderliness got merged resulting in slight improvement in the reliability of the SLEQ. Consequently four factors with eigenvalues greater one were rotated using a varimax rotation procedure. Table 5 shows the loadings obtained as a result of the factor analysis. The rotated solution as shown in Table 5 yielded the following four interpretable factors: supply material environment, integration, supervision, and reliable material environment. With the deletion of five items from the SLEQ, the 18-item, four-factor solution was decided upon as the optimal structure for the final version of the perception instrument. Each of the remaining items had a factor loading of approximately 0.50, far higher than the conventionally accepted value of 0.30 for analysis involving individual students as the unit of analysis (Fraser, McRobbie, & Giddings, 1993).

Table 5

Rotated component matrix showing factor loadings and amount of variance explained for the final SLEQ

	Factor			
Item Number	1	2	3	4
8	709			
13	708			
2	660			
20	650			
7	602			
22		754		
15		679		
1		616		
6		565		
12			698	
9			679	

Table 5 cont'd

	Factor			
Item Number	1	2	3	4
18			634	
10			488	
17			486	
21				589
5				588
3				587
23				552
% of explained Variance	23.5	10.2	9.2	6.7
Eigenvalue	4.22	1.83	1.66	1.20

Decimal points omitted. Factor 1= supply material environment, Factor 2= integration, Factor 3= supervision, Factor 4= reliable material environment

The percentage of total variance explained by the four factors is quite large (49.5%), given that the individual means was used as the unit of analysis. The structures of the eigenvalues show a slightly dominant first principal component. The amount of variance between respondents explained by the first factor is 23.48%. The results of the factor loadings in Table 6 show that the first component ranged from 0.60 to 0.71. This means that all the respondents had a high and positive correlation with the first principal component. The inter-correlations among supply material environment were the highest among the four factors (Table 5). This component was interpreted as the extent to which laboratory equipment and materials are available and adequate. The four psychosocial scales that emerged in this study, their interpretations and the Moos category to which they belong are given in Table 6.

Unlike the instrument developed by Fraser, McRobbie and Giddings (1993), (which served as a guide for the development of this instrument), the final SLEQ makes a clear distinction between two types of material environment as described in Table 6. All the learning environment inventories surveyed had only one description of material environment. In the pilot study therefore, availability and adequacy of science equipment and materials were clearly distinguished from the reliability of such equipment and materials used in science laboratories.

<u>Item Analyses</u>

Item analyses procedures were conducted on the set of 18 items making up the SLEQ. Table 7 presents alpha coefficients for the four SLEQ scales using the individual student as the unit of analysis. Coefficients range from 0.61 to 0.76, exceeding the threshold of 0.60 given by Nunnally, cited in Henderson, Fisher and Fraser (1998) as being acceptable reliability for research purposes. The overall Cronbach's alpha coefficient was 0.84. There were very low neutral responses ranging from 0.3% to 2.6% suggesting evaluative quality of the instrument.

Table 6

Scales and descriptions of the final SLEQ

Scale	Moss Category	Description
Supply material environment	S	Extent to which laboratory equipment and materials are available and adequate
Reliable material environment	S	Extent to which laboratory equipment and materials are reliable when used
Supervision	R	Extent to which students receive help and are guided by their teachers during science practical activities
Integration	P	Extent to which laboratory activities are integrated with non-laboratory theory classes

Also the data generated by items of the SLEQ are distributed across Likert's continuum, which also suggests evaluative quality. The final SLEQ is shown in (Appendix D).

Table 7

Internal consistency (Cronbach alpha coefficient) and variance of each scale of the SLEQ

Scale	Alpha reliability
Supply material environment	0.76
Integration	0.65
Supervision	0.69
Reliable material environment	0.61
Total	0.84

In summary, the pilot study identified four factors (scales) that underlie the measure of students' perception of their psychosocial laboratory environment. These are supply material environment, reliable material environment, integration and supervision. A series of item and factor analyses of the SLEQ led to the evolution of a refined version of the SLEQ which was found to display satisfactory internal consistency reliability and factorial validity using the individual as the unit of analysis. This refined SLEQ was used for the main study.

Questionnaire on the Organisation of Science Practical Work (QOSP)

This questionnaire was designed after small-scale investigations by the researcher on how science practical lessons were organised in three SSS in the Cape Coast Municipality. Discussions between the researcher and nine of the science teachers (one each in biology, chemistry and physics) in the three schools who had been organising practical activities in their schools enabled the researcher to write the questions for the QOSP. This also ensured that major areas of concern to teachers on the organization of science practical work were addressed in the formulation of the questions by the researcher. The formulated questions were pre-tested in two schools (an SRC school and one of its Satellite schools in the Central Region) with the aim of ensuring that the QOSP fairly and comprehensively covered the items it purports to cover. The responses of the teachers were used to improve the questions. The supervisors of the researcher were also asked to comment on the suitability of the questions. These processes led to a refinement of the questionnaire.

The final questionnaire had several parts. These included sections on biographical information (e.g., years of teaching experience, subject(s) taught at the SSS level), organisation of science practical activities (e.g., support given to students, number of times practical work is done on the average each week). The QOSP is shown in Appendix E.

Questionnaire on the Role of Science Practical Work (QRSP)

This questionnaire was designed after small-scale investigations by the researcher on science practical lessons in three SSS in the Cape Coast Municipality. Discussions between the researcher and nine of the science teachers (one each in biology, chemistry and physics) in the three schools who had been conducting practical activities in their schools enabled the researcher to write the questions for the QRSP. This also ensured that major areas of concern to teachers about science practical work were addressed in the formulation of the questions by the researcher. The formulated questions were pre-tested in two schools (an SRC school and one of its Satellite schools in the Central Region) with the aim of ensuring that the QRSP fairly and comprehensively covered the items it purports to cover. The responses of the teachers were used to improve on the questions. The supervisors of the researcher were also asked to comment on the suitability of the questions. These processes led to a refinement of the questionnaire.

The final questionnaire had several parts. These included sections on biographical information (e.g., years of teaching experience, subject(s) taught at the SSS level), role of science practical activities (e.g., types of science practical activities and the skills involved. The QRSP is shown in Appendix F.

Interview Protocols for Students, Heads of Science Departments and SRC Co-ordinators

Semi-structured interview protocols were designed to collect data from students, Heads of Science Departments and co-ordinators of SRCs. The semi-structured approach to interviewing was used, mainly to gather descriptive data in the subjects' own words so that insights could be gained into science practical activities. Semi-structured interview schedules were prepared for each category of respondents (see Appendices G, H, and I). The use of semi-structured interviews also allowed the researcher to raise issues of particular concern to the study. The interview schedules were therefore not used rigidly so that interviews could proceed as naturally as possible.

Data Collection Procedure

The fieldwork was conducted in two stages: the first took place between October 2001 and December 2001 and the second, April 2002 to June 2002. The April 2002 fieldwork was a follow up to generalizations that emerged from quantitative analysis of the first fieldwork data. It also served as a validation exercise for the findings of the survey conducted in the first fieldwork.

With a letter of introduction from the Head of Science Education Department of the University of Cape Coast, the researcher visited the selected schools and introduced himself to the various School Heads and staff of the Science Departments. The first fieldwork involved data collection from 10 SSS from the Central Region of Ghana. Data collection lasted three days in each school. The ASP and SLEQ were distributed to students in each school. Questionnaires on the role and organization of science practical activities in SSS were given to the science teachers to complete. Out of 60 sets of questionnaires given out, 50 sets were completed and returned. The ASP was administered by the researcher to selected students on the first day. Students were allowed enough time to complete the ASP after which the SLEQ was given to them. The students completed both questionnaires at one sitting. This was done to ensure that the same students completed both sets of questionnaire and to prevent the mortality of the questionnaire. The completed questionnaires were collected by the researcher the same day.

There were two sets of teachers' questionnaire. The first set, which dealt with the role of science practical activities, was also administered on the first day with the assistance of the Heads of Science Departments and the second on the organization of science practical work the next day. As much as possible, all questionnaires administered to science teachers were collected by the third day. Cases of non responses were followed up thrice before attempts to obtain the completed questionnaires were abandoned. This procedure resulted in a return rate of 83%.

Follow-up visits were made to four of the schools during the second fieldwork. The fieldwork at this stage consisted of only interviews, which were conducted by the researcher. In each of the four schools, focus group interviews were conducted with four to six science students (depending on the number of streams in the school). The students were made up of the Class Prefect, and another student randomly selected by the researcher. In the case of schools with only one stream, the students involved in the focus group interview were made up of the Class Prefect, the Assistant and two other students randomly selected by the research. Focus groups in each school were made up of the class prefect(s) and others selected by simple random sampling by the researcher. The co-ordinators of two of the four selected schools, which had SRCs were interviewed by the researcher using a semi-structured interview guide. All interviewees were given assurances of confidentiality and anonymity at the beginning of each interview session. All student interviews took place in a quiet and comfortable environment with little possibility of distraction or intrusion so that students could talk freely. All interviews conducted in the study were recorded using an audio tape-recorder supplemented by note-taking with permission of the interviewees. The Heads of Science Departments of the four selected schools were also interviewed. The purpose of this interview was to seek deeper insights into issues, which emerged from analyses of responses to science teachers' questionnaires and student interviews. To ensure consistency and preserve the validity of the study, similar data collection techniques were used in all the four case study sites, namely:

(i) semi-structured interviews that focused around the key identified issues of the study;

(ii) observation of science practical write-ups of 10 students including those interviewed;

(iii) physics, chemistry and biology SRC practical handbooks published by the MOE and used at the resource centres for practical activities

Two types of documents were sought and used in this study. The first was the physics, chemistry and biology practical write-ups of all students who took part in the interview sessions. These were examined to find out the type of practical activities students had undertaken, their frequency and relationship to the science syllabuses. The second was the physics, chemistry and biology source books used by students and teachers at the Science Resource Centres as a guide to practical activities.

Data Analysis

Differences between perceptions of the science laboratory environment held by students in the different types of schools (satellite and SRC) were analysed using one-way multivariate analysis of variance (MANOVA). Differences in attitudes of students towards science practical work the SRC and satellite schools were also analysed using MANOVA. The corresponding one-way univariate analysis (ANOVA) with school type as the independent variable was examined for each of the SLEQ and ASP scales individually as a follow up test to the MANOVA to determine whether significant differences exist between school-type on each scale.

To determine whether associations exist between students' perception and attitude, simple correlation were conducted in addition to using the standardised regression weight (beta), which characterises the associations between an attitude scale and a particular perception scale when all other perception scales were controlled or held constant.

Qualitative data gathered during interviews were analysed by reducing them to patterns and themes and then interpreted to amplify the quantitative data to provide insights into science practical activities in SSS. In using the 'theme approach' (Hitchcock & Hughes, 1992), the researcher has to transcribe all the interviews. Even though this was time consuming it helped to create familiarity with the data in the researchers' mind and hence aided the process of analysis.

CHAPTER 4

RESULTS AND DISCUSSION

Introduction

In this chapter, the findings from the study into science practical work in Ghanaian SSS are presented and discussed in relation to the three hypotheses and five research questions. The hypotheses and research questions are discussed based on quantitative analysis that compared means of students in satellite and SRC schools on variables such as attitude and perception. Qualitative data gathered during interviews with Heads of Science Departments (HODs), students and co-ordinators of SRCs in case study schools, are used to complement and substantiate findings. The statistical and qualitative analyses of the data from of the study are presented in five sections:

(a) Students' perceptions of their psychosocial science laboratory environment

(b) Students' attitude towards science practical work

(c) Associations between students' attitude and psychosocial science laboratory environments

(d) Teachers' views on the role of science practical activities in the teaching and learning of science

(e) Organisation of science practical activities in SSS

QUANTITATIVE ANALYSIS

Students' Perception of their Psychosocial Science Laboratory Environments

Research question one sought to find out the factors if any, which underlie students' perception of their psychosocial science laboratory environment. The study identified four factors (scales) through factor analysis. These are:

(a) supply material environment

(b) integration

(c) supervision

(d) reliable material environment

Table 8 shows the factors, their meanings and how much of students' perception of their psychosocial science laboratory environment are explained by the four factors.

The percentage of total variance explained by the four factors was quite large (50.5%), given that the individual means was used as the unit of analysis. The structures of the eigenvalues show a slightly dominant first principal component (supply material environment). The amount of variance between respondents explained by supply material environment is 26.8%. This means that supply material environment is a dominant factor influencing how students perceive their psychosocial science laboratory environments.

Table 8

Description of factors underlying students' perception

Scale	Description	% of variance explained	Eigenvalue
Supply material environment	Extent to which laboratory equipment and materials are available and adequate	26.8	4.8
Reliable material environment	Extent to which laboratory equipment and materials are reliable when used	9.3	1.7
Supervision	Extent to which students receive help and are guided by their teachers during science practical activities	8.4	1.5
Integration	Extent to which laboratory activities are integrated with non-laboratory theory classes	6.0	1.1

Research question two sought to find out the factors if any, which underlie students' attitude towards science practical work. The study identified three factors that underlie SSS students' attitude to science practical work through factor analysis. These are:

(a) learning tool

(b) equipment

(c) interest

Table 9 shows the factors, their meanings and how much of the attitude towards science practical activities are explained by the three factors.

Table 9

Description of factors underlying students' attitude

Scale	Description	% of variance explained	Eigenvalue
Learning tool	Extent to which science practical activities help in the learning of science	40.8	5.71
Interest	Extent to which students are interested in science practical activities and write-ups	8.9	1.25
Equipment	Extent to which students like working with science equipment	8.4	1.17

The percentage of the total variance of 58.1% explained by the three factors was quite large according to Fraser, McRobbie & Giddings (1993) given that individual means was used as the unit of analysis. The structure of the eigenvalues shows a dominant first principal component (learning tool). The amount of variance between respondents explained by the learning tool is 40.8%. This means that science practical activities as a learning tool for the study of science concepts is a dominant factor influencing the attitude of students towards science practical work. This confirms the assertion by Woolnough (1998) that students like practical activities aimed at discovering or elucidating theory. The amount of variance explained by interest and equipment was only 8.9% and 8.4% respectively.

Hypothesis one

Hypothesis one states that there is no significant difference between the factors underlying the scales (or linear combination of the scales) of SRC and satellite school students' perceptions of their psychosocial science laboratory environment. To test this hypothesis, school type-related differences in perceptions of students were explored using one-way multivariate analysis of variance (MANOVA) with the set of SLEQ scales as dependent variables and type of school as the independent variable. The MANOVA test presented in Table 10 shows that Wilks' lambda (Λ) value of 0.91 was statistically significant, F (4, 383) = 9.20, $p < .05$, indicating the hypothesis that the population means on the scales are the same for SRC and satellite schools cannot be supported, and was therefore rejected.

Table 10

One way MANOVA on SLEQ scales and category of school

Effect	Value	F	Hypothesis df	Error df	Significance
Category of school	0.92	9.20	4.00	383.00	.001*

Significant *$p < .05$

This result showed a significant difference (in favour of SRC students) between the perception of students in SRC and students in satellite schools of their science laboratory environment. The corresponding univariate analysis of variance (ANOVA) with school-type as independent variable was therefore examined for each of the SLEQ scales individually as a follow up test to the MANOVA to determine whether there were significant differences between school-type on each scales. The scale means, differences in means and standard deviations and F ratio for SRC and satellite school students' responses on the perception instrument are shown in Table 11. The table shows that the ANOVA on supply material environment was significant, F (1, 386) = 29.45, $p <$ .013 but no significant type of school differences were found on the other three scales (integration, supervision and reliable material environment).

This means that students from SRC schools perceived significantly a more favourable supply material environment than their counterparts in satellite schools. This result is however, not surprising for SRC schools, since their laboratories are expected to be very well-equipped.

Table 11

Univariate ANOVA on each scales of the SLEQ as a follow up tests to the MANOVA

Scales	Mean		Standard Deviation		F	Significance
	SRC	SAT	SRC	SAT		
Supply material environment	15.27	12.60	4.84	4.84	29.45	.01*
Integration	16.11	15.23	3.50	3.60	5.98	.15
Supervision	17.92	17.80	4.99	4.30	0.06	.06
Reliable material environment	13.21	13.05	3.69	3.75	0.18	.68

Significant *$p < .0125$, N = 204 (SAT); N= 184 (SRC)

A less favourable perceived supply material environment could arise if equipment and materials are not replaced when they get damaged or are exhausted. Also, increase in population of students pursuing science programmes could outnumber the quantity of equipment and materials available in schools. Case study evidence from this study clearly indicates that in some schools both explanations are tenable. Evidence from interviews analysed later in this chapter shows that satellite schools, which could have taken advantage of a better supply material environment in SRCs, did not avail themselves of this opportunity. Mean scores for the items constituting supply material environment are reported in Table 12. It can be seen from Table 12 that mean scores for items 2 and 13 were below the average of 2.50 in satellite schools indicating that students felt the quantity, availability and supply of equipment and materials were unsatisfactory in these schools. The mean scores of the rest of the items on this scale for satellite schools were only a little above average. Since this scale accounts for more than a half of the total variance of students' perceptions of their psychosocial environment, it is a very important factor to be considered in setting up science laboratories to promote science practical activities in schools. Science laboratories without the necessary equipment and materials for the recommended practical activities in the WAEC syllabus would definitely not make a good impression on students. Students from both type of schools however, had similar perceptions of the reliability and use of science laboratory equipment and materials reliable material environment.

The higher than average scores on this scale for both school types and the fact that there was no significant difference between them shows that to some extent there some workable apparatus in the science laboratories in both school types.

In summary, the results of this study show that students' general perception of their science laboratory environments in both SRC and satellite schools were positive but significantly different in favour of students in SRC schools.

Table 12

Mean scores for items constituting supply material environment in SRC and SAT schools

Item No.	Supply material environment	Scale Mean		Standard Deviation	
		SRC	SAT	SRC	SAT
2	We have enough equipment in our school laboratories for science practical	2.93	2.28	1.30	1.27
7	Our school laboratories have enough room for individual/group work	2.80	2.75	1.58	1.61
8	Our school laboratory is an attractive place to work	3.63	2.68	1.37	1.51
13	The equipment/materials students need for practical are readily available in our school laboratories	2.86	2.24	1.33	1.31
20	We are supplied with all the equipment we need for our experiments in our school laboratory	3.05	2.65	1.37	1.48

N = 204 (SAT); N= 184 (SRC); Average score = 2.50.

Students from SRC schools expressed significantly higher satisfaction with the quantity, availability and supply of equipment and materials in their science laboratories than their counterparts from satellite schools. This factor seemed to have dominated students' perception of their psychosocial environments. This finding implies importantly that if the Ministry of Education would want to improve science laboratory environments in schools, then it needs to give priority attention to the quantity, availability and supply of equipment and materials in their science laboratories. The difference between the perception of students in SRC and satellite schools may reflect the laboratory conditions in these schools. However, there was no significant difference in how students from both type of schools perceived the reliability and use of equipment and materials in their science laboratories (Table 11). Also students from both SRC and satellite schools appear to enjoy very high and similar levels of supervision and integration (Table 11).

Material environment and integration as factors influencing students' perception of their learning environments have been reported in studies by other researchers (Fraser, McRobbie & Giddings, 1993; Henderson, Fisher & Fraser, 1998; Chin & Wong, 2001; Raaflaub & Fraser, 2002). For example, Chin and Wong (2001) reported that in Singapore, primary school pupils surveyed indicated they wanted a much better material environment for the study of science. However, unlike these studies, which have only one material environment as a factor, this study found two types of material environment, which were clearly distinguishable.

Even though integration as a factor influencing students' psychological perceptions of their laboratory environment has been reported in the literature, Supervision which has not yet been reported in the literature was found in this study to be a factor underlying students' perceptions of their science laboratory environment in both satellite and SRC schools.

Students' Attitude towards Science Practical Work

Hypothesis two

Hypothesis two states that there is no significant difference between the factors underlying the scales (or linear combination of the scales) of SRC and satellite school students' attitude towards science practical work. To test this hypothesis, school type-related differences were explored using one-way multivariate analysis of variance (MANOVA) with the set of attitude scales as dependent variables and type of school as the independent variable. The MANOVA test presented in Table 13 showed that Wilks' lambda (Λ) value of 0.94 was statistically significant, F (3, 383) = 7.72, p < .05), indicating the hypothesis that the population means on the scales are the same for the two types of schools (SRC and satellite) cannot be supported, and was therefore rejected. The results of this analysis indicate that students in SRC schools had significantly more positive attitude to science practical work than students from satellite schools.

Table 13

One way MANOVA on ASP scales and category of school

Effect	Value	F	Hypothesis df	Error df	Significance
Category of school	0.94	7.72	3.00	384.00	.001*

Significant *p < .05

This is not surprising as SRC schools have relatively better laboratory facilities than satellite schools. Since the findings show that attitude towards science practical work is influenced by equipment and its use in helping students learn science concepts and practical skills, schools with better facilities for science practical work will definitely have an advantage over those without them. The corresponding univariate analysis of variance (ANOVA) with school-type as independent variable was therefore examined for each of the ASP scales individually as a follow up test to the MANOVA to determine whether there were significant differences between school-type on each scale. Table 14 presents the scale means, differences in means and standard deviations for SRC and satellite schools. The ANOVA on interest and equipment were significant, $F(1, 386) = 18.22$, $p < .01$ and $F(1, 386) = 9.76$, $p < .0125$ respectively.

Table 14 however, shows no significant difference between students in SRC and satellite schools on the learning tool scale which is the most dominant factor influencing attitude of students towards science practical work.

Table 14

Univariate ANOVA on each scale of the ASP as a follow up tests to the MANOVA

Scales	Mean		Standard Deviation		F	Significance
	SRC	SAT	SRC	SAT		
Interest	20.83	18.99	2.99	5.11	18.22	.001*
Equipment	13.33	12.53	1.97	2.91	9.76	.002*
Learning tool	26.05	25.25	4.20	5.52	2.50	.115

Significant *$p < .0125$, N = 204 (SAT); N= 184 (SRC)

This means that between SRC and satellite schools, differences in attitude between students arise from interest in science practical work and equipment in science laboratories rather than the learning aspect. Better and more modern equipment in both school types as well as increase in the frequency of practical activities by students can therefore easily generate more interest in practical work. Better equipment in SRC school laboratories compared to those in most satellite schools could therefore explain the difference in attitudes between students of the two school types. This finding is however, not surprising for SRC schools since their laboratories are supposed to be very well-equipped. As already pointed out, evidence from interviews shown later in this chapter shows that satellite schools, which could have taken advantage of better facilities at SRCs, did not avail themselves of this opportunity.

The use of science practical activities as a learning tool according to the results of this study has the most influence among the three scales identified on the attitude instrument. The finding that there is no significant difference between students of the two school-types on the learning tool scale suggests that irrespective of the school-type, students have positive attitude towards practical work since they feel it helps them understand science concepts. Findings by some science researchers (e.g., Bogden, 1977; Buchweitz, 1981; Edmonson & Novak, 1993; Waterman, 1982) which suggest that most students gain very little regarding the understanding of science concepts through practical activities is not supported by findings in this study. Findings from this study rather upholds the assertion that practical work offers an essential opportunity for students to link first-hand experience in the form of practical work with concepts and ideas (Christofi, 1988, von Secker & Lissitz, 1999). Mean scores for the items constituting learning tool are reported in Table 15. It can be seen from Table 15 that the mean scores for all the items on learning tool were far above the average of 2.50 indicating a very positive attitude on the learning tool.

In summary, the results of this study indicate that students' attitude towards science practical activities in both SRC and satellite schools are highly positive, but significantly different in favour of students from SRC schools. The results also show that students' attitudes towards science practical work are influenced more by the learning aspect of laboratory work than interest in science practical work and the use of equipment during practical work.

Table 15

Mean scores on items constituting learning tool

Item No.	Item Description	Scale Mean SRC	Scale Mean SAT	Standard Deviation SRC	Standard Deviation SAT
5	Science practicals help me to understand the theory taught in class	4.38	4.38	0.98	1.06
11	Science practicals make me appreciate science better	4.43	4.15	0.82	1.26
12	Science practicals help me to understand what I learn in the classroom	4.29	4.19	0.92	1.22
16	Science practicals help me acquire scientific skills	4.54	4.31	0.75	1.11
19	Science practicals help me to learn science better	4.32	4.19	0.99	1.13
25	I understand science lessons better after doing science practicals	4.10	4.04	1.20	1.22

N = 204 (SAT); N= 184 (SRC); Average score = 2.50

However, there was no significant difference in the attitude of students from both types of schools on the learning tool scale. The differences between the two school-types were due to equipment and interest factors.

Associations between Students' Attitude and Psychosocial Perception

One objective of this study was to investigate the associations between students' attitudes towards science practical work and perceptions of their science laboratory environment. This was also done for SRC and satellite schools separately as it had been established that there are significant differences in attitudes and perceptions of students in these two school types generally, and especially, on some individual scales. In order to find out the associations between attitude and perception, Pearson correlation coefficient (r). Hypothesis three was formulated and tested for all students combined, SRC students only, and satellite students only respectively.

Hypothesis three

(a) There is no significant association between students' perception of their psychosocial science laboratory environment and their attitude towards science practical work in SRC schools.

(b) There is no significant association between satellite students' perception of their psychosocial science laboratory environment and their attitude towards science practical work.

Table 16 shows the simple correlation coefficients (r), which describes the bivariate association between the perception and attitude measures. An examination of simple correlation coefficients (Pearson product moment correlation coefficient, r) reported in Table 16 shows there were no statistically significant relationships between attitude and perception measures for students in both SRC and satellite schools.

Findings from this study showed that students' attitude towards science practical work was not related to their perception of the school laboratory environment, in both SRC and satellite schools.

Table 16

Pearson product moment correlation analysis of students' perception and attitude in SRC and SAT schools

Variable	N	r	significance
Attitude vrs Perception (SRC students)	184	.016	.833*
Attitude vrs Perception (SAT students)	204	-.021	.769*

*Not significant, $p>.05$

QUALITATIVE ANALYSIS

Teachers' Views on the Role of Science Practical Work

Introduction

In Ghana, like many other countries, there is a strong tradition of doing practical work in school science. This is because there are vigorous assertions of the claims of the usefulness of practical work by the MOE and WAEC science syllabuses. The key aims of the SSS science syllabuses are essentially the attainment of scientific knowledge, and the development of practical skills and attitudes. According to the science syllabuses, it is expected that this would normally take place in conventional laboratory environments. It is widely acknowledged that for many students, scientific concepts may be abstract and difficult to grasp, hence teachers use different methods including practical activities to improve student understanding of such concepts. Practical work is considered to be effective as it allows students to change the abstract to the concrete, thus helping in the internalisation and understanding of concepts (Arce and Betancourt, 1997). There is however, a growing body of evidence indicating that despite this emphasis on practical work much school science teaching is unsuccessful in giving students an understanding of the ideas of science and development of some scientific skills (Clarkson and Wright, 1992; Hodson, 1992). It is in the context of these views and findings that this section explores science teachers' views on the role science practical work plays in the teaching and learning of science in Ghanaian SSS.

Essential Role of Science Practical Activities

Teachers were asked on the "Questionnaire on the role of science practical work" to specifically to state what they considered to be the essential functions of science practical work in the teaching and learning of science in schools. Teachers' views on the essential functions of practical work were that of helping students to develop practical skills, elucidating theory taught in class and developing scientific attitudes.

The spectrum of views expressed by teachers (Appendix J) can be categorized into the following three:

Science practical activities

(a) help students understand the concepts or theoretical aspects better and this aids teaching and appreciation of science;

(b) enable students to develop practical skills, collect, record and analyse data, and;

(c) enable students to verify facts and principles that are taught in class.

Teachers' Reasons for Organising Science Practical Activities

When the 50 teachers were asked to rank the reasons for organising practical work, Table 17 shows that they ranked low, reasons for organising practical work which were related to helping students arrive at new principles, and seeking for problems, and find ways to solve them (see Appendix K for the basis for the ranks). This confirms similar findings by other researchers elsewhere (Kerr, Thompson, Beatty & Woolnough as cited in Woolnough, 1998).

They also ranked low, reasons related to satisfying WAEC examination requirements, and helping students pass practical examination. These rankings were in agreement with views expressed by teachers in open-ended questions on the same issue. Reasons related to using practical work to clarify theory taught in class were ranked high, whilst those related to verification of facts and

Table 17

Teachers' ranking of reasons for organising science practical activities

Reasons	Rank
To use science practical to clarify theory	High
To verify facts and principles already taught	Medium
To arouse and maintain interest in science	Medium
For students to develop specific manipulative skills	Medium
To encourage accurate observation	Medium
To enable students understand the theory better	Medium
For finding facts and arriving at new principles	Low
To satisfy the science syllabus and WAEC examination requirements	Low
To enable students pass their final examination	Low
To practice looking for problems and seeking ways to solve them	Low

acquisition of manipulative skills were ranked medium by teachers. It has been shown earlier on in this study that learning tool, the extent to which science practical activities help in the learning of science was the most influential factor affecting the attitude of students towards science practical activities. It must be noted that these reasons for organising practical work ranked high or medium by teachers are in line with the prescriptions of the science syllabuses. The views of students and teachers of the role of science practical work is essentially that of helping students understand theory or content taught in the science class.

It seems this role of science practical work has taken the centre stage in the teaching and learning of science and has become the main reasons, though not exclusively, for conducting practical activities in schools. This is evident from the results shown in Table 18.

Table 18

Mean scores and percentage responses in each category for each item (N=50)

Type of science practical	Always	Very Often	Often	Rarely/ Never	Mean
Practical to verify theory already taught in class	30.0	50.0	16.0	4.0	3.04
Practical designed to help students develop laboratory skills	20.0	44.0	32.0	4.0	2.82
Practical designed to help students develop scientific attitudes	12.0	42.0	36.0	10.0	2.58
Project work designed by students based on a problem of their choice	0	2.0	38.0	60.0	1.42

The table shows that generally, teachers organised practical activities to verify theory more often than not (96.0%). The majority of teachers (80.0%) with a mean of 3.04 indicated they always (30.0%) or very often (50.0%) conducted such practical activities. According to students in school Z for example, the few practical activities they had done had helped them to understand some of the theory already taught in class. Students in school X also indicated that they liked practical work because of its value in helping them understand theory. For example, two students said:

> Once I found the theory on the simple pendulum difficult but one practical we did helped me to understand better the relationship between the variables later on. If we had done more practical, it would have helped me to understand the theory better (Student, School Z).
>
> For me what I like about practical work is being able to apply the theory directly to the practical (Student, School X).

The HOD of school X agreed with these students on the use of practical work to aid understanding of theory because according to him he had been using this approach with success with his students. He observed that

> ...it is unfortunate some science teachers don't make use of practical. For instance if you allow the students to perform the practical teaching the theory becomes easier, and because they have done it, they have seen it so now you can talk about abstract things. So far as they are starting from

the known, I mean from a point when they know what can happen if you talk about it, they will also believe it...But unfortunately, for some teachers, I don't know why they don't want to perform it, thinking they want to cover more of the theory, but rather it makes teaching difficult for them. They don't realise that and it doesn't make the boys enjoy the science. (HOD, School X).

Ironically, according to Barton (1998), "many of the criticisms levelled against practical work focus on difficulties related to teaching 'theory' through practical work" (p. 238). The HOD of school X and students in schools X and Z however, lauded the idea of using practical work to clarify some of the principles and theories taught in science lessons. Evidence from this study shows that using practical work in this way accounts for over 40.0% of students' attitude towards science practical work. Students saw the value in practical work as helping them better, to understand science theory they learn in the classroom. Students' experiences with practical work, limited as they were, seem to dispute the claims by Woolnough (1991) and Hodson (1990) that students do not learn scientific concepts for themselves when doing practical work since the knowledge is already known. However, evidence from this study shows that the knowledge could be known, but students may not necessarily understand it very well. Finding out information for themselves through practical work is a useful exercise as claimed by the students, regardless of whether or not that knowledge is already known. It is therefore plausible that practical work when implemented properly and creatively could increase students' learning of scientific concepts as acknowledged by some students and teachers in this study.

The mean scores also indicate that teachers more often tended to conduct practical activities with the intention of developing laboratory skills (2.82) followed by developing scientific attitudes (2.58). The table however, shows a very low mean of 1.42 with 60.0% of the teachers indicting that they rarely or never allowed students to design and perform their own experiments. This confirms the assertion that teachers placed more emphasis on using practical work to help students understand science theory followed by the development of manipulative skills thereby giving students very little opportunity to identify their own problems, play a role in the design of appropriate experiments, collect and interpret data themselves. Since students rarely pursue such activities, it would be difficult for students to develop cognitive skills associated with problem solving. Studies by Hannon (1994) and Arce and Betancourt (1997) have shown that when students are allowed to design their own experiments, they become motivated, curious, enthusiastic and confident. According to them students find practical work challenging and rewarding as a result of this. Also Hodson (1990) acknowledges the fact that if students are allowed to pursue their own investigations in their own way through practical work; it can result in higher motivational power. It is therefore disappointing that majority of teachers (80.0%) stated that they did not allow their students to design and try experiments on their own. In assigning reasons for this, some teachers mentioned lack of equipment in schools. Others stated that practical work was guided by WAEC syllabuses and that there was no time and room for such individual adventurism. According to one of the teachers, "we do only practical work guided by the WAEC syllabus" (see Appendices L and M for the spectrum of views expressed by teachers). This means that experiments were specific and related to those suggested by the syllabuses and in some cases where equipment were available. The problem of time constraint was the most cited reason by teachers for not allowing individual students the liberty to perform their own designed experiments. According to those who gave this reason, there was so much work to do in completing the science syllabuses that students would not have the time to design and carry out their own experiments. Some teachers also felt that it would not serve any purpose for students to design their own experiments and carry them out, and pointed to the nature of the WAEC syllabuses for science and the final WAEC practical examination, which they said did not allow for or reward individuals for designing their own experiments. Others thought it was not feasible for each of the over 50 students in their class to design experiments and carry them out since as they put it "there will be confusion in the laboratory". About 20.0% of teachers who indicated that they allowed their students to carry out individual investigations also stated that students did so for science exhibitions during speech and prize-giving days in their schools. Only two teachers (4.0%) gave reasons related to encouraging students to be innovative and creative. The teachers however, pointed out that students designing and performing experiments on their own could only be done with very few students as teachers need to supervise such students. Without doubt the type of practical activities emphasized by teachers was related to WAEC practical examinations even though they denied it when they ranked low, reasons, which suggest that they do practical work to satisfy the science syllabus and WAEC examination requirements.

Teachers were also asked to rank ten practical skills in terms of importance in science practical work. Three out of the ten skills were related to development of attitudes, two directly related to laboratory skills and the rest on cognitive skills. Table 19 presents the results of the rankings (see Appendix N for the basis of the rankings). The table shows that teachers ranked high or medium all the attitudinal and laboratory skills. General scientific skills such as predicting, drawing conclusions and hypothesizing, which are related to the development of cognitive skills but not necessarily laboratory based were all ranked low. This is not surprising as the final WAEC practical examination has very little if anything at all to do with the development of cognitive skills. However, the skills which teachers ranked low (predicting, drawing conclusions and hypothesising) are rather those that can lead to the development of understanding of the concepts and procedures involved in science which students need to acquire. Laboratory skills such as observing and manipulation are not complete in themselves as they only constitute the first hand experience phase of science practical work. This should be followed by analysis and interpretation of the data collected. The link between the two phases enables students to relate the first hand experience to the appropriate concepts. Unfortunately, Barton (1998) has observed that "too often the time and effort expended in collecting and processing the data tend to squeeze out activities related to analysis and interpretation" (p. 238) of data.

Table 19

Teachers' ranking of practical skills in terms of importance

Practical skills	Rank
Observing	High
Manipulative	Medium
Initiative	Medium/High
Objectivity	Medium
Integrity	Medium
Problem formulation	Medium/High
Experimental design	Medium/Low
Predicting	Low
Drawing conclusions	Low
Hypothesising	Low

Without analysis and interpretation, it would be difficult to link practical experience with abstract concepts. However, helping students to make this link is an important process, and one, which should form the core activity during science practical activities.

Summary on Role of Science Practical Work

In summary, evidence from the study suggests teachers' view of the role of science practical activities were dominated by the desire to help students understand theory. Emphasis was placed mainly on those practical activities that could help elucidate theory and develop manipulative skills, though teachers recognized the acquisition of attitudinal skills as essential. Even though teachers ranked very low reasons for conducting science practical activities which are related to satisfying science curriculum requirements and helping students pass WAEC practical examinations, other evidences from the study suggest that this was not true in practice. It is therefore not surprising that students' attitudes towards science practical activities are dominated by the extent to which science practical activities help in the learning of science.

Laudable as it is for individual students to design and carry out their own experiments, this was not the general practice in the schools. The evidence from the schools show that very little or no emphasis was placed on the development of higher-order skills in science which could help students develop understanding of concepts and procedures involved in experimentation. To do this will require students to be given the opportunity to explore, test and reason, using data not necessarily generated by students. Students had virtually no opportunity to identify their own problems, play a role in the development of appropriate experiments, and collect data and interpret data themselves. Reasons given by teachers suggested that in some cases they saw the performance of practical work as fulfilling a requirement for the final WAEC practical examination even though it could have been used to encourage ingenuity, initiative, creativity and innovation on the part of students through the designing and carrying out their own designed experiments. Also, even if teachers would like individual students to design and try out their own experiments, time constraint and unavailability of equipment are likely to frustrate such an attempt.

Organisation of Science Practical Activities in Schools

Performance of Science Practical Activities

Given that the essential functions of practical work is geared towards helping students understand theory and prepare them for the final WAEC practical examination, an attempt was made to find out how science practical activities were organised in SSS using the case study schools. Questionnaires for teachers and interviews with students and heads of Science Departments were used to explore this issue.

The science syllabuses aim to help students acquire attitudinal and process skills. Sections of the introductory parts of the science syllabuses relating to these skills are as follows:

Physics

(a) develop abilities, attitudes and skills that encourage efficient and safe practice;

(b) develop attitudes relevant to science such as concern for accuracy and precision, objectivity, integrity, initiative and invectiveness.

Source: Regulations and syllabuses for the WAEC senior school certificate examination, 1998-2000 (p.459).

Chemistry

(a) enable students to develop laboratory skills, including an awareness of hazards in the laboratory and the safety measures required to prevent them;

(b) enable students to appreciate the scientific method which involves experimentation, accurate observation, recording, deduction and interpretation of scientific data

Source: Regulations and syllabuses for the WAEC senior school certificate examination, 1998-2000 (p.120-121)

Biology

(a) acquisition of necessary scientific skills for example observing, classifying and interpreting biological data;

(b) acquisition of adequate laboratory and field skills in order to carry out and evaluate experiments and projects in biology.

Source: Regulations and syllabuses for the WAEC senior school certificate examination, 1998-2000 (p.77)

It requires a lot of consistent science practical activities for these objectives to be achieved. However, a look through students' science practical notebooks and subsequent interviews with them revealed clearly that much attention was not paid to practical work in physics, chemistry and biology in the first two years of the science programme in all the four case study schools. It was not possible to ascertain the number of practical activities performed by science students just by looking at the records in their science practical notebooks. This is because in all the case study schools, students did not keep proper records of practical work done. It came to light during interviews with students that practical activities were sometimes not recorded by students into their practical notebooks or when recorded were not properly written up. Also students were allowed to use pieces of paper to record and write up practical work they had done. Some of the practical exercises, which had been marked, did not show dates and/or titles of the practical activity. A look through practical notebooks students could make available gave the impression that even though students may have done a lot of practical work, particularly in the third year, much attention was not given to the write-ups.

Table 20 shows the number of practical activities performed by students over a period of almost two and half years at the time of this study (interview of students was conducted in the third term of the academic year between May and June, 2002).

Generally, students in SRC schools performed more practical activities than their counterparts in satellite schools. According to the students, some of the practical activities were recorded on pieces of paper and so were lost.

What appears in Table 20 are the number of practical activities recorded in notebooks, pieces of paper and what students remembered they did over a period of nearly three years (SSS1 to SSS3). Where zero appears in the table, the students insisted that they did not perform any practical activities during that year.

A look at students' practical notebooks revealed that over half the practical activities done were not marked. The picture portrayed by Table 17 is that generally, students performed very few practical activities during the first two years in school. As one student in school X puts it

> In this school, we normally suspend the practical to form 2 third term and form 3 (SSS3). So in form 1 (SSS1) and form 2 (SSS2) we seldom do experiments. So we didn't do a lot of practical...the teacher was saying that because of our number we can't be doing practical with the form 2 (SSS2) and the form 3 (SSS3) students. At least we've got more time so our practical work could be suspended for some time so that when we get to SSS3 we will do more practical (Student, School X).

Since students had to be prepared for the WAEC practical examinations at the end of the third year, it is not surprising that more practical activities were done during the third year. Table 20 shows that in all the schools except school X, students did not perform any physics and chemistry practical in SSS2. At least school Y could not complain about lack of apparatus because it had an SRC. Students in schools Y and Z did not also perform any chemistry practical activities in SSS1. Also there was virtually no biology practical work for school W.

The situation in biology was not different in school Z, except that the teachers decided to make up for practical work lost by doing more practical (10) with their students in SSS3.

The situation for physics practical work in school Z was worse than the rest of the schools. According to the students, they performed only one physics practical in SSS1 and this was on "Finding the refractive index of a glass block". They could not even complete this practical and their notebooks confirmed this. In SSS2 they did not perform any practical activities in physics at all. In fact at the time of this study, the students had performed only two practical activities in SSS3. The second practical was conducted on 26th January 2002 on the "Determination of the refractive index of glass using illuminated objects" as indicated in their notebooks.

This was marked and discussed with the students. Both practical activities done in SSS3 were on light experiments leaving experiments on mechanics, electricity, heat, and sound undone. The first experiment in mechanics performed by students in school Z took place during the mock practical examination in May 2002. According to one of the students speaking on behalf of her colleagues:

> The teacher told us to go and read about it. So we read about it and came to apply it in the examination. We were able to take the readings and tabulate the results but how to come with the graph was difficult. So we couldn't plot the graphs. Another problem we got was that as we swing the pendulum we wasted more time on it so some of us couldn't

Table 20

Number of practical activities performed and recorded in physics, chemistry and biology by school type

School/Subject		Number of practical/Class			
		SSS1	SSS2	SSS3	Total
Physics	School Type				
W*	SAT	1	0	10	11
X*	SRC	2	5	6	13
Y	SRC	4	0	5	9
Z	SAT	1	0	2	2
Chemistry					
W*	SAT	1	0	9	10
X*	SRC	5	5	6	16
Y	SRC	0	2	6	8
Z	SAT	0	6	4	10
Biology					
W*	SAT	1	0	0	1
X*	SRC	3	5	5	13
Y	SRC	2	5	14	21
Z	SAT	0	0	10	10

*Highest number of practical activities in schools with more than one stream finish the experiment. (Student, School Z).

In the mock examination in school Z, students were asked to measure the diameter of the pendulum bob without being provided with vernier callipers. The account of one of the students on how he tackled the measurement of the diameter of the pendulum bob is quite revealing:

> I have not seen vernier callipers before...I don't know whether we have micrometer screw gauge here... Yes it was in the question but that one, I didn't do it because we were not having the micrometer screw gauge or vernier callipers (Student, School Z).

The lack of practical activities in school Z, being a less-endowed school, may seem to be an extreme case but it is not too different from that of School W which in comparison is a better endowed school. In the whole of form one in school W, Table 17 shows that there was only one practical activity each in physics, chemistry and biology. According to the students, the chemistry practical activity in form one was based on a past WAEC practical examination question and students could not make much of it at the time. One student remarked:

> I remember our chemistry teacher gave us a question but he didn't show us anything about it. He just gave us the practical question to do. (Student, School W).

The only physics practical performed by students of school W was on finding the "Density of an irregular object". Again a student remarked:

He showed us how to do the practical and we wrote them in our notebooks. We did the practical but we didn't record it on a paper for him to mark (Student, School W).

Students in school Y (SRC school) who had done relatively more practical work than those in school Z (satellite school) were worried that even though they had done more experiments in SSS3 than in SSS1 and SSS2 combined, they thought they still had a lot more practical to do before the final practical examination conducted by WAEC.

It is fair to note from the case study evidence, that emphasis was not put on the performance of science practical work in schools especially in the first two years. Sometimes lack of teachers accounted for the inability of students to do practical activities. For example, the lack of a biology teacher accounts for students in school Z not having any biology practical activities in form one. But the same thing cannot be said for the lack of physics practical activities in the same school in form one. There was a physics teacher who had not conducted any practical sessions with the students. The other school had teachers but it is clear that practical sessions were scanty in both SRC and satellite schools.

We were not going to the lab very often to do practical. Some of the students and the teachers did not take the practical classes seriously. Most of us thought that since we were in form 2 *(SSS2)* maybe there was more time ahead so it is actually in form 3 *(SSS3)* that we started practical so we didn't take the practical seriously from the beginning

(Student, School W; italics mine)

In school W the HOD agreed to the suggestion that much emphasis was not put on science practical work when students are in SSS1. He however, defended this practice by saying that

> We have a reason for that. The time table doesn't cater for science practical work. We have six periods for physics, and within those six periods, which is two periods a day, you cannot organize science practical. So it is not the fault of the teachers that the students do not do physics practical. At the same time if you look at the syllabus there are so many things to cover and so you have to rush. So you are forced to cover most of the syllabus in the lower forms and later towards form 3 *(SSS3)* then you do science practical with the students (HOD, School W; italics mine).

However, an attempt is always made in the final year to make up, somehow, for practical work neglected in SSS! and SSS2, so that at least students would be able to take the WAEC science practical examination. The nature of the questions in the WAEC practical examination promotes this lack of emphasis on regular practical work. Some of the teachers indicated that some areas in the WAEC practical examination could be handled by students once they are conversant with the theory. The WAEC biology practical examination is made up of the following five areas:

(a) graphs (drawing and interpretation)

(b) classification

(c) identification of specimen

(d) description of experiments (supposed to have been conducted by students)

(e) drawing of specimen

According to some teachers and students, (a) to (c) constitute techniques which could be taught with virtually no practical activities. It is only (d) and (e) that students need to have practiced to be able to describe or perform in the practical examination. If this is the case then it means some of the practical activities relevant to the WAEC biology practical examination do not relate strictly to laboratory tasks but to general cognitive competencies. However, it seems that though teachers may be aware of these contexts in which practical work could be used, since the over-riding concern was to make students pass the WAEC examination, emphasis was put on the last one and even then mostly in the third year to the neglect of the other uses. Fortunately, in physics and chemistry, practical work makes up for only 20%, and so poor performance may not adversely affect the final grades of students who perform very well in the theory aspect of the examination. However, in biology practical work takes as much as 30% of the total marks for the biology examination. Students' performance in biology is more likely to affect their final grades in biology compared to physics and chemistry. However, if the claim by teachers that a sizeable amount of the biology practical examination could be handled by students without necessarily going through practical work, then the lack of practical work may also not adversely affect students who have mastered the theory work in biology.

Another issue that came up for discussion during focus group interview of students was practical examination at the end of the term. The case study produced comments from students and evidence that suggested that practical examination was rarely conducted by the schools either at the end of the term or year. Apart from school Y where students said they took end of term practical examination on two occasions, none of the other three schools organized any science practical examinations. Some comments from students attest to this.

> The mock examination was the first practical examination we took
>
> (Student, School Z)
>
> Our first practical exam was the mock exam in April. This was the second term in the third year. In form two we were told that we will do practical exams but they kept postponing (Student, School X).
>
> Here we only have practical exams during mock because the mock is supposed to be like the final exam (Student, School W).

The case of these four schools has provided considerable evidence to confirm allegations made by Chief Examiners' in the sciences over the years that the nature of students' weaknesses in the practical examination cast serious doubts on students' involvement in practical activities during their science course giving the impression that they were either not taken through the practical activities or did not take them seriously. This view has been acknowledged in the comments and views expressed by students, HODs, and teachers in the schools. It would however, be misleading to suggest that science teachers were unappreciative of the need for practical activities to be performed by their students. The wider picture from this study suggests that mitigating circumstances (lack of teachers and equipment, large class sizes, overloaded curriculum) constrain schools and teachers to overlook the performance of science practical. Interviews with HODs confirmed this.

In school Z for example, the HOD admitted that the school had not got enough apparatus to do practical work. In physics, items such as cells, metre rule, calorimeters, vernier callipers, weights, micrometer screw gauge etc were not available in the school and had to be borrowed from another school over 20 km away. No doubt school Z is a typical poorly resourced school and clearly does not meet the conditions set by the science syllabuses of having a well-equipped laboratory in order for the school to offer science. The situation in school Z is indeed very discouraging and puts a limit on the number of practical activities students could have.

The students in this school were expected to go to the SRC some 20 km away since their laboratory was poorly equipped. However, this was not for free as the school had to pay for fuel as well as consumables for the practical activities particularly in chemistry and biology. The school did not have the money to pay these bills any time students had to go to the SRC. Also since the number of students in SSS3 was only 15, it was not cost effective transporting this small number of students in a big bus, which takes over 70 students. Because of this situation, students in SSS3 had never been to the SRC for the two and half years they had been in the school. The HOD of school Z indicated that where apparatus were available for the kind of science practical activities teachers wanted students to perform, students were made to do them. However, during mock and final WAEC practical examinations they always borrowed apparatus from other schools to enable students take the examinations. One therefore wonders how students could out of the blue and with very little experience in practical work be able to perform experiments in WAEC science practical examinations without adequate experience and exposure particularly when the instructions from WAEC to the science teachers categorically state that the purpose of the practical test is to find out whether the candidates can carry out simple practical work themselves.

Sometimes the inability of students to conduct practical activities was due to the cost involved. For example, the HOD in school X indicated that for chemistry practical alone the school had to purchase about 5 to 6 million cedis worth of equipment before students could take the final WAEC examination. This means that conducting practical activities is very expensive but students do not necessarily pay more for offering science. Due to this, expensive practical work could therefore not be done on regular basis.

> Of course the number of students in the classes completely overshadows the number of laboratories that we have…we have not been able to cover the syllabus using the normal time. We have to use afternoon classes. That is what we have been doing over the years. If you use the normal time you will not finish and those who are not prepared to go into extra classes they are the people who are not performing the practical (HOD, School X).

It is very clear from the comments by the HOD of school X that there is inadequate time even for the coverage of science theory prescribed by the syllabuses and this affected practical work. All the HODs shared this opinion. Since the number of periods allocated for science lessons (ranging between 6 to 8 periods a week) is not enough, the priority therefore was for teachers to concentrate on the theory and make up for the practical work later. Time constraint appears to be a particularly serious problem as the HODs used it to justify the inability of science teachers to conduct adequate science practical activities with students. The reasons given by the HODs suggest that teachers are not ignorant of the need for practical work but the constraints of time make them put more emphasis on the theory aspect.

> Sometimes when you look at the coverage of the syllabus I am sure that with time, teachers have realized that they should rather spend time giving the students theory then when they have gotten enough they can take them through the practical (HOD, school X).

The belief is that somehow students would be able to perform the practical in the final examination once they get some little exposure. To enable students get exposure, practical activities are organized at the last minute during the third term for students. This state of affairs required that students did a number of practical activities within a period of one or two hours. To prevent the situation where students had to wait for one group to complete their practical work before others had their turn, three or more different experiments are set up so that whilst some groups are doing one kind of practical activity, others would be doing different experiments and after completion the groups swap. In all the case study schools, students were made to perform more than one practical activity during any practical session especially during the students' final year. Whilst half of the students will be in one room performing one set of practical activity the other half would be in another room performing a different set of practical activity and after an hour they switched over. It looks like the science teachers always wanted to use the limited time available to conduct as many practical activities as possible, particularly, in SSS3 when they see that students had not done enough practical work. According to students in school X, sometimes they performed as many as five practical activities in groups within two hours.

> Sometimes for only three periods we are made to do so many different practical activities sometimes four different practical; one on resonance tube, sonometer box, one on heat, one on electricity (Student, School X).

During this period emphasis on practical work is examination driven, as the following comments seem to portray:

> Essentially, what is happening now is that we are only training the students to go and pass the examination. Honestly, if the practical is supposed to serve a purpose then it is supposed to complement the theory. But here is the situation where you have done the theory and you are now coming to do the practical so it's not serving any purpose. The practical is supposed to help them pass the examination (HOD, School W).
>
> Probably, the teachers look at the end result of their teaching. So whether they teach practical or not if at the end of the day students do well in science examination then that justifies the approach they have been using. (HOD, School X)

In the well-endowed schools in this study, more than half the number of students presented for the examination are able to make grades A to D and this probably tends to justify the approach of teaching the theory and doing practical work getting to the final WAEC examination period in SSS3. This situation is not the same for less-endowed schools. The approach of teaching mostly theory and very little practical in less-endowed schools due to whatever constraints has not yielded similar results as those in well-endowed schools. Teachers in less-endowed schools tend to blame the students for their poor performance. The comment from the HOD of school Y (less endowed) summed it up in this way:

If you look at the amount of work we put in for them and their results they are not comparable at all. I am putting in a lot of energy going to the extent of explaining everything to them (HOD, School Y)

In summary, there was ample evidence from the interview results and observation of students' record of practical work done lead to the conclusion that practical activities were not organized regularly for students, particularly, when they are in forms one and two. It is evident from the result of this study that students did not form the habit of recording practical activities in their exercise books. Students therefore did not have consistent record of practical work done. Some of the practical work recorded by students had no date and heading. For some practical work there was virtually no write up at all. Science practical work was considered important for students to pass their WAEC practical examination. This state of affairs has come about as a result of many constraints, the major ones being lack of time, overloaded curricula, lack of equipment and large class sizes. In the next section, difficulties teachers and students face in organizing and performing science practical activities respectively are explored.

Difficulties Associated with the Organisation of Science Practical Work

Another focus of the research was to find out difficulties teachers faced in trying to organise science practical activities as well as those faced by their students. It was expected that science teachers and students in SRC schools may not have the same difficulties as those in satellite schools with respect to apparatus, materials and equipment. The findings of the study show otherwise.

Science teachers from both SRC and satellite schools enumerated problems in three areas. These are (a) lack of apparatus and equipment needed for some of the practical activities, (b) time constraint coupled with work overload and, (c) lack of trained laboratory assistants. In the SRC schools, teachers complained about insufficient apparatus for some of the practical activities they wanted to conduct. In most cases therefore, it was not a question of non-availability of equipment or apparatus but rather adequacy. If apparatus are either not available or insufficient in some SRC schools, then teachers do not know where else to turn for help. In the satellite schools, teachers complained about poorly equipped laboratories, sometimes with no water flowing. The apparatus where they were available were either limited in quantities or faulty. Teachers from satellite schools indicated that they had to borrow equipment from other schools regularly to be able to perform practical activities with their students. According to the teachers, it is the limited number of equipment, which made them, put students into groups. However, as one teacher puts it "equipment may be available but limited in number and therefore there may be more students per group than desired". Perhaps it is this frustration that sometimes makes teachers decide not to conduct science practical activities until the last minute. Biology teachers for example, complained about difficulty in getting the right specimen and reagents for practical work whilst chemistry teachers complained mostly about lack of chemicals. According to the teachers, they found it easier getting the heads of the schools to release money to purchase apparatus and materials for the final WAEC examination than for normal school practical work. Sometimes it seems that if school heads do not come from a science background themselves they may not see the need in committing so many resources into major items of expenditure on students' routine science practical activities or on science curriculum issues in general. Teachers in SRC schools conceded that the SRC has been of tremendous help to them because they get most of the items needed for practical activities from the centre. This explains why equipment was a factor influencing attitude of students especially in satellite schools.

Time constraint in the face of what the teachers called an "overloaded curriculum" coupled with the limited number of periods available to complete the science syllabuses appear to be a particularly serious problem for many teachers. One teacher in an SRC school indicated that "because of the fact that I am the only teacher teaching elective biology, my practical classes are large". For this teacher the absence of a laboratory assistant made his work extra difficult. In fact, most of the teachers complained about either the absence of laboratory assistants or where they were available, sometimes were not very useful because they were either watchmen or labourers who had been converted into laboratory assistants. Such laboratory assistants were unable to offer the kind of assistance needed by teachers or students. Consequently, every bit of preparation for practical work had to be done by the science teacher. This situation becomes burdensome, particularly, for chemistry teachers when there has to be a lot of preparation of solutions before practical activities can take place.

Asked about what problems students had with science practical activities, teachers enumerated a wide range of problems, which cut across satellite and SRC schools. Some of the problems were however, peculiar to the less-endowed schools. According to some science teachers in both SRC and satellite schools, because of inadequate facilities in the schools' laboratories, students found it difficult appreciating the importance of practical work. This supports the finding that students' perception of their science laboratory environment is greatly influenced by the availability and adequacy of equipment in both SRC and satellite schools. Teachers confirmed that most times students only get access to the laboratory when they get to upper forms (SSS2 and SSS3). Also students were forced to work in groups due to lack of adequate number of equipment and space. This made participation in practical activities by all members of a group impossible. Many students therefore end up not benefiting from practical activities due to insufficient time to set up the apparatus themselves and take their own readings. Consequently, students have difficulty handling glassware and working independently when it comes to examinations. Teachers also indicated that students get frustrated with practical work due to faulty apparatus. It is therefore not surprising that students' attitude to science practical work is influenced by the use of equipment. According to one teacher in a satellite school "in electricity for example, experiments may start with readings in turns by students but later there may be inconsistency in the readings due to faulty apparatus resulting in wrong results and graphs". Time constraint prevented students from performing adequate number of practical activities. This made students feel less confident when it came to practical work. The result of this inadequate exposure to practical activities and lack of practice was that students could not read measuring instruments accurately or plot graphs using their results. Teachers indicated that students had difficulty interpreting and discussing biological data. These are concerns that have been raised in Chief Examiners' reports for biology over the years. This may be partly because of inadequate exposure to laboratory training and practice as documented earlier in this work.

Normally, students enrolled for science in some schools have very weak entry grades in science and mathematics and according to the teachers this was a major contributory factor to their inability to perform well. Other major problems faced by students as enumerated by teachers were:

(a) students' failure to follow instructions;

(b) students' difficulty with the plotting of graphs after they had collected the data particularly when the readings are in decimals; and

(c) students working with improvised equipment which may not be very efficient or reliable

Time Allocation for Science Practical work

Time allotted for science constitutes a critical dimension of the problem of lack of practical work in the schools as seen in the previous section. In this section, the issue of time is explored in more detail using responses and comments from both case study schools and survey data.

Asked whether practical periods were officially allocated on time tables, 38.0% of science teachers stated that their time tables did not show any time for practical work. The remaining 62.0% who indicated that their time tables had periods allocated for science practical work gave a range of two to four periods per week for such activities. Practical periods therefore differed from one school to the other as well as across subjects. These periods were seen to be inadequate by 68.0% of the teachers. Actually 76.0% of the teachers indicated that school hours used for practical work ranged from two to three periods of 40 minutes duration per period. In schools where practical periods are allocated on the time table, most teachers normally use them for theory work. In school X for example, there were three periods for practical work and five periods for theory but most teachers used all the eight periods for theory. According to the teachers, this was even not sufficient and some teachers had to resort to afternoon classes for the teaching of more theory. Some teachers used some afternoons and weekends to do practical work. However, doing practical work after school has its own disadvantages.

Sometimes students are punished for not coming for practical work. At other times nothing is done to them. Many people don't come for practical work particularly for physics because we do it after school. In chemistry because we do it during classes time many students turn up (Student, School W).

Most times we don't go to the laboratory. The teachers don't organise the practical for us and the students don't go for practical even when it is organised (Student, School X).

The HOD for school X had a reason for students not turning up for practical work particularly after school hours. According to him

The students probably do not like the practical because when they came in we did not help them to develop the interest. The affective aspect is missing (HOD, School X).

Teachers were asked to indicate whether students were able to complete laboratory work and the subsequent write up within the period allocated for science practical. The responses are presented in Table 21. From the table only about half of the teachers (52.0%) indicated that students normally complete their laboratory work and write-up within the time allocated for practical activities and this ranges between 45 minutes to two hours. The study has already established that students sometimes do multiple practical activities within this period. It is therefore not surprising that nearly half of the teachers indicated that students did not complete both laboratory work and the write up within the practical work period. The table shows that 88.0% of the teachers indicated that more often than not students only complete the laboratory work.

Table 21

Percentage responses in each category on completion of laboratory work and write-up (N=50)

Item	Always	Very Often	Often	Never/Rarely
Students complete their lab work and write up	8.0	14.0	30.0	48.0
Students complete only lab work	20.0	50.0	18.0	12.0
Students do not complete lab work	0	4.0	12.0	84.0

This shows that the write up of the practical work is pushed to "after school" as data collection dominates the practical time.

Students and the HOD in school X in this study confirmed this when asked whether they did their practical write up in the laboratory.

> It depends on the practical. Since it is two experiments a day for two hours, maybe you might not finish the first one before an hour is over. So you go and do the write up in the house (Student, School W).

> We normally finish the practical work but we don't write it up. We only take the readings (Students, School X).
>
> Because of the limitation of time they get their readings and then they retire to do the write-up (HOD, School X).

The write up of practical work at the SSS usually involves the following steps:

- (a) title and date of experiment;
- (b) list of apparatus;
- (c) diagram;
- (d) method;
- (e) precautions;
- (f) observations;
- (g) deductions;
- (h) graph;
- (i) calculation;
- (j) conclusion;
- (k) sources of error.

When students mention practical write up they were referring to going through all these stages. The evidence from case study schools shows teachers were not particular concerned about practical write up by their students in the way outlined above. Students also did not like doing the write up because they either saw it as unnecessary or a waste of time as they are mostly not marked and discussed with them. A look through students' practical notebooks and the pieces of papers presented for inspection shows that where students did any write up it was mostly limited to observations, deductions, graph and calculation.

According to the students this is not even looked at and marked by teachers in most cases thus confirming their belief that the write-up was not necessary.

> When we do the practical the main concern is just how to get the values. That is the main thing we do towards the SSSCE. So in many cases we don't do a complete write-up. So far as we get our values and plot our graphs, we are okay. The main thing they are concerned with is the graph or how we get the table. So we don't normally write up the practical systematically (Student, School X).
>
> When we go to the laboratory a question is given to us, like maybe a past question is given us. We use that in doing the practical. We are more concerned with getting used to the instrument than writing up the whole thing (Student, School W)
>
> We have a lot of practical on electricity. But the ones that he has marked are three. The rest we just try our hands on them and go and plot our own graphs (Student, School X).

It seems the main concern was for students to go through the practical activity and take some readings. What students do with the results and graphs plotted is sometimes not the concern of anybody. This seems to be a common practice in the schools. Driver as cited in Wardle (1998) rightly reflected on this common approach to practical work when he stated that:

> practical lessons end abruptly when the prescribed task is complete and little, if any, time is given to the interpretation of the results obtained, although this is just as important as the activity itself (p. 272).

Even though the emphasis on collecting data provides perspective and context for the students, it is the ability to interpret and reason, which is a higher order skill in science, that develops the understanding of the concepts and procedures involved (Wardle, 1998). It is therefore clearly invalid and unconvincing in terms of developing students understanding of science for them to just collect data in the name of carrying out practical work without allowing them to question, reason and draw conclusions from the data collected. However, even if the emphasis is on students using practical work in school as a way of practicing for the final WAEC examination the HOD of school X thinks that:

> it is unfortunate that the practical students do, are not marked. Because it is only when you mark and discuss with them that they will build confidence (HOD, School X).

In fact some students even thought the write up was not necessary and that once they understood what they had done when it came to the examination they would be able to perform.

> ...here is the case about one and half months or two months ago we have done only one practical. So it is like we just write it up in a kind of jotter or something and then we don't even know where we've even kept the book. But apart from that we make sure that we understand what we have done and how to go about the practical so when it comes to the examination we will be able to write. But as to record and put them in a document or like have it in a book for reference, we don't have anything like that (Student, School X).

> We are taught in the classroom on how to draw the table, write the units and plot graphs. All that we have gone through in the classroom. So when we go to the laboratory and do the experiment, the write ups are not so necessary. We just take our values and leave. When we go the laboratory a question is given to us like maybe a past question is given us. We use that in doing the practical. We are more concerned with getting used to the instrument than writing up the whole thing (Student, School W).

Some students stated that sometimes their teachers came to class to check their graphs. However, without the teacher thoroughly going through students practical notebooks to see what they had done, there is the possibility that even though students have been taught what to do during practical, they still could have been making errors which might not be detected by the teacher. It is only through correction, and reinforcing achievement that students will develop the kind of skills teachers expect through practical activities. It seems that sometimes in a rush to do more practical work all these important issues are overlooked.

Time constraint and lack of interest on the part of some students combine to make practical work in some schools unattractive. In school X for example, the lack of interest in practical work on the part of some students as pointed out by the HOD might have stemmed from the teachers inability to encourage practical activity. The following comment by a student in school X buttresses this point.

> I must say that if practical work in my class was encouraged I don't think people will feel lazy or become reluctant in doing practical work. Because right from the very onset, if it has been put into us that we should be serious with practical work I don't think we will be having problems now (Student, School X).

These comments go to confirm the notion that some teachers do not put high premium on regular practical activities and this affects the morale of students. This is blamed however, on time constraint, which becomes a convenient excuse for not organising practical work for students. Some teachers are also not prepared to do extra classes with students in the afternoon or during the weekends so that they could have time for practical work. Students on the other hand are apathetic to practical work because of lack of emphasis by their teachers and so even when they are asked to go for practical work they feel reluctant. However, since there is already a lack of commitment to practical work on a regular basis on the part of teachers, they overlook students' lack of interest, thus making practical work optional.

In summary, what the evidence in this study on time allocation for practical work shows is that schools have different number of periods for practical work. In some schools there are no periods at all allocated for practical work on the official school time table. Teachers therefore conduct practical work as and when they deemed it necessary. Even where practical periods are fixed on the time table, teachers normally use them to teach theory. Laboratories for science in such schools are therefore widely underutilized, or wrongly utilised for traditional whole class teaching (Caillods, Gottelmann-Duret & Lewin, 1996)

Use of Textbooks and other Materials for Practical Work

Practical teaching of science in school laboratories in many cases consists of 'cook-book' exercises designed for students to go through. According to Jenkins (1998) a survey of practical work in school laboratories shows that the use of laboratory manuals was a model over the first half of the 19th century. The use of textbooks for science practical work has since that time become a regular feature the world over. According to Caillods, Gottelman-Duret and Lewin (1996), in most countries where print materials are widely available, there exists markets, which produce and distribute curriculum materials other than those officially recognized. Schools in Ghana however, seemed not to share in this common occurrence when it comes to books or manuals for science practical activities. In the sample schools, 88.0% of teachers stated that they did not know of any approved textbooks for science practical activities. The other 12.0% made reference to the Ghana Science Association of Teachers (GAST) textbooks as the approved textbooks for practical work. However, GAST textbooks are approved for the teaching and learning of science by the MOE but are not specifically for practical work. However, there are suggested practical activities to be performed by students in the GAST textbooks. One cannot therefore say that GAST textbooks are like standard manuals for practical work. Unlike the situation in some other countries, most teachers and students did not have access to books or manuals produced by parallel markets. About 88.0% of teachers stated that their students did not use any books when performing science practical activities. The 12.0% of teachers who stated that their students use science practical textbooks when performing experiments listed books such as Biology Practical for SSS by Dan Dare, Investigations in biology for tropical schools by Leslie Allen and SRC Practical Books as textbooks. Teachers who indicated that their students did not use any standard textbooks listed some of the following as sources of practical activities for their students:

a) selected past WAEC questions
b) practical Chemistry (SAMKOFSEL's series)
c) practical pamphlets
d) practical Physics for schools and colleges by Bredan O. Ahuche
e) prototype experiments from past GCE and SSSCE examination papers

f) experiments designed by science teachers

g) suggested experiments in GAST textbooks

h) practical handout prepared by science teachers

The use of different textbooks or manuals suggests that no standard science practical activities take place in schools as students look into different textbooks or manuals for practical activities. Table 22 shows the proportion of teachers who used different references for practical activities. The table shows that most of the time (88.0%) practical activities performed by students are taken from WAEC past examination practical questions and textbooks particularly, the GAST textbooks. It can be seen from the table that the majority of teachers (66.0%) rarely or never used pamphlets.

The different sources of science practical work shows that there is no standardization across schools or even within schools on materials students use as reference for practical work. The science syllabuses contain numerous suggested practical activities. The chemistry syllabus for example, has a list of topics on general skills and principles, quantitative analysis, and qualitative analysis. However, it is not surprising that none of the teachers mentioned the science syllabuses as reference materials for practical work in their schools as anecdotal evidence shows that teachers do not use either the WAEC or teaching syllabuses given by the MOE. The frequent use of WAEC past questions is not surprising since this study has established that most teachers organized science practical to enable their students have some confidence to take the final WAEC examination.

Table 22

Percentage responses in each category on the source of materials for laboratory work (N=50)

Item	Always	Very Often	Often	Never/Rarely
Designed by me	18.0	24.0	34.0	24.0
Taken from textbooks	6.0	24.0	56.0	14.0
Taken from pamphlets	2.0	12.0	20.0	66.0
Taken from WAEC past questions	12.0	34.0	42.0	12.0

Use of Group Work during Science Practical Activities

Performing experiments in groups is a regular feature in Ghanaian SSS in Ghana. Students are put together and given the task of performing practical activities. It is therefore not surprising that 90.0% of teachers indicated that their students work in groups during science practical activities. The evidence from the study shows that students usually work in groups of four or five. This seems to be the average with the maximum being 10 and the minimum 2. Group work took place in schools with large class sizes of 50 or more as well as in those with small class sizes of 15 due to inadequate equipment. According to the HOD of school X, it was not possible to get students to perform practical work on individual basis.

> For instance given a class of 50, I have to divide them into two groups of 25 each. Whilst one batch is writing the theory the other batch is performing the practical and then they switch. It is not possible to get them to do practical on individual basis due to shortage of equipment (HOD, School X).

In schools with very large class sizes, the number of students far out number the quantity of equipment and consumables in the laboratories, and so the situation described by the HOD of school X is understandable. According to the HOD, teachers in his school decided that after students had been introduced to practical work in groups they would create a situation where students could have individual practice in science practical work. Individual practice is essential since the purpose of the final WAEC practical examination is to find out whether the candidates can carry out simple practical work themselves. However, according to the HOD, this could not happen due to insufficient equipment even with an SRC in the school. In school Y which had an SRC and an SSS3 science population of 34, students performed physics practical activities in groups except when they had practical examination due to insufficient equipment. However, according to the students in school Y, chemistry and biology practical activities were sometimes done on one to one basis, but then the class had to be divided into two groups for this to be possible. School Z had only 15 science students in SSS3, yet because they did not have enough equipment this prevented them from performing science practical work on individual basis. They therefore had to wait and perform the practical work in turns. The following statements describe the situation in chemistry, for example:

> In chemistry we don't have enough pipettes and burettes. We have about six. The burettes are old and the demarcations have all become so faint you can't see them. So sometimes you have to wait for your friend to finish so that you can collect his burette (Student, School Z).

It can therefore be concluded that one of the constraints that give rise to use of group work in schools was inadequate equipment and materials. Comments from students in school W buttress this point.

> Sir we don't know whether the equipment are around but they are not being used. Because in physics we are assigned to work in groups of three. For chemistry we have about six people to a group. The teacher will tell us that he doesn't want us to waste chemicals, so we have to work in groups. In biology we don't know whether the equipment are enough but they just don't want you to damage them so we work in groups. In biology the microscopes are not enough. So they are placed at vantage points for us to use (Students, School W).

Judging from the evidence from this case study, it appears that the key determining factor for group work was inadequate equipment and materials or the fear that students may damage them. However, group work could be used to the advantage of students. Students could collaborate with each other to perform science practical activities. For collaborative learning to occur students in groups could interact among themselves and encourage the establishment of positive relationships. However, the important issues of group success being dependent on and a direct effect of, the individual work of each member of the group seem to be absent in the case study schools. Instead the evidence shows that there were clear differentiated power relationships among members in a group as in many cases individual students assumed a directive role as the following comments from students indicate:

> One person or two people will do the whole practical so those of us who are not performing the practical will tend to sit and then just watch (Student, School X).
>
> The disadvantage is where he does it and you always sit down not practicing. And then he is always doing it and you will just be watching. So you won't have a feel of it and if you don't take time on the D-day that you are supposed to do it yourself you might be found wanting, though you have been watching him do it, it might happen that you wouldn't be able to pick it up (Student, School X).
>
> Some people will feel lazy in a group because they know that oh my friend will do it...at times some students even don't come to the laboratory because they know they work in a group they will just copy what others have done (Student, School W).

> Sometimes we become so dependent on our friends we don't normally do the work ourselves because one sharp person is within our group we all depend on the person. He takes the readings and we all copy. Sometimes this annoys the person doing it (Student, School Y).
>
> Particularly in the physics we depend very much on those who understand. So we will be sitting there for the person to do it and we copy. So if the person is doing the wrong thing we just copy (Student, School Y).

One reason for the above situation is the fact that group sizes become too large leading to overcrowding around the experimental set up and therefore some students naturally do not get the opportunity to engage in the task assigned. Others hide behind group work presentations and therefore intentionally do nothing to enable the group complete its task. In the end, students do not gain much from practical work. Group work therefore becomes a drawback to the performance of practical activities. Majority of students would therefore not acquire any skills as the students themselves have indicated. It is therefore difficult to see the purpose of such practical work. This situation is exacerbated by the limited time at the disposal of students to complete the practical work in order for other group of students to get the opportunity to perform their tasks. The following quotations from two students succinctly describe the effect of overcrowding in their school laboratories during practical work:

> When we work in groups we are overcrowded and people tend to sit on the fence especially when we are in groups like that. Not all of us can put our hands together to do the practical at the same time. One person or two people will do the whole practical so if you are not performing the practical, you tend to sit and then you just watch (Student, School X).
>
> In chemistry there are six people in a group. Everyone will like to perform the activity and sometimes that brings confusion since we are asked to take three readings (Student, School W).

Another disadvantage of the type of group work done in the case study schools was that of shared responsibilities during group work. According to students some of them decide to perform some aspects of the practical, leaving others to perform the rest. The following comments from students in school X illustrate this point:

> Let's take chemistry for example; you are supposed to take three readings for the titration. So maybe the first person will do the first one and will give it to you to do the second one and a third person to do the third one. And then the others might be calculating the values for you to be fixing in the table (Student, School X).
>
> Taking chemistry for instance, our teacher is not usually with us. So when we start maybe you might ask someone to come and take the

second reading. He might tell you that he would want to go for the solution instead, or maybe he might swallow some of the solution if he tries to pipette so he chooses not to do it (Student, School X).

Another reason for students not participating fully in the performance of practical work is the lack of pre-lab sessions and sometimes the absence of teachers in the laboratory during practical work. When students don't know what to do they tend to look up to one person. In school Y, for example, the HOD who happened to be the physics teacher mentioned that one of the students in the class was very good and understood the practical work very well. Focus group discussion with students revealed that those who found themselves in the same group with this particular student allowed him to perform the practical activities on their behalf. This was because they did not usually understand the tasks assigned them and the teacher was not there in most cases to help them. This situation gives rise to some students monopolizing practical work not because they are selfish but rather due to the circumstances in which they found themselves. Surprisingly, case study students defended the monopoly of practical work when it was suggested to them that some students intentionally monopolize practical work.

> Yes you are right. But sometimes it is not their fault. Because maybe for a given practical the others doing it may not know anything about it so you have to monopolize and do it (Student,

School X)

> It is not our fault that we monopolize the practical. But then some of the students are not willing to do it. If you ask them to do it, they will tell you that they can't do it or something of that sort. You just tell him the value that's all (Student, School W).

> To the best of my knowledge, sometimes if you talk of the monopoly within the students themselves is like the first person who will go and sit behind the set up is the one who is going to monopolize the practical (Student, School Y).

These comments show that there were virtually no democratic and negotiated styles of working which has been shown to be linked to higher motivational levels and greater all-round understanding than those in which an individual student assumes a directive role (Hodson, 1993). Students sitting together in groups and letting one of them to do all the work while others watch or listen, should not be considered as cooperative learning. It is evident from the evidence in this study that students sometimes did, not get the opportunity to practice or find things out for themselves during group practical activities. The benefits of group work were therefore lost to such students. It is therefore safe to conclude that part of the reasons why students exhibit numerous weaknesses in science practical examination may be due to the way science practical activities are organized in schools.

Support Given to Students During Science Practical Activities

One way of reducing frustration on the part of students during science practical work is supporting them before and during practical activities. In the teachers' questionnaire therefore, teachers were asked about support systems put in place to enable students cope with science practical activities. During focus group interviews, students were also asked to indicate the kind of support they received and the source of that support. All the science teachers indicated that they gave support to their students during practical work. About 42.0% of science teachers indicated that they and their laboratory assistants gave support to students whilst 20.0% of the teachers indicated that students received support from only science teachers. Another 22.0% indicated that students received support from science teachers, laboratory assistants and their fellow students. Asked to state who students receive most support from, 76.0% of the teachers stated that they provided the most support to students. The support listed by teachers fell into the following categories:

(a) finding out whether students were doing the right thing;

(b) helping in identification, drawing and labelling of specimen;

(c) correcting wrong experimental procedure as well as checking and correcting faulty equipment;

(d) helping students so that they would not injure themselves or damage any science apparatus;

(e) giving hints to students who are unable to proceed as a result of their inability to understand some points in the theory of an experiment;

(f) helping students focus specimens under the microscope;

explaining the theory behind the practical activity.

Case study evidence shows that pre-laboratory discussion in the schools depended on which teacher was involved. In some schools, some teachers organised pre-laboratory discussions whilst others did not. Also sometimes teachers who organised pre-lab on one occasion did not do so on other occasions. There is no standard practice when it comes to organising pre-lab for practical activities.

The different kinds of support enumerated by science teachers constitute the spectrum of support given to students. According to Hodson (1993) the "only effective way to learn to do science is by doing science, alongside a skilled and experienced practitioner who can provide on-the-job-support" (p. 120). However, the evidence from the case study schools shows that the support given to students differs from one science subject to another and also from one school to another. In fact, in some cases students indicated that no support at all was given to them. In the case study schools, students were asked about how helpful their teachers were when it came to practical work, and whether their teachers were always present to give support. Also students were asked about the kind of support they received from other students. In school Z, for example, students indicated that they did not receive much support during practical activities in physics but their biology and chemistry teachers together with the laboratory assistants and their own colleagues gave them a lot of support. Students in school W also indicated that they received a lot of support from their chemistry teachers but not from their physics teachers. The following comments from students' sum up how they sometimes received support from their teachers during practical work in the various science subjects.

> In chemistry the teacher will explain everything to us and give us an example, and set up the apparatus for us to do. When we have any problems the teacher is there to help us (Student, School Z).

> For the few physics practical we have done the teacher was very helpful. He went round and showed us how to do things. But for chemistry he just gives us the apparatus and expects us to be able to go through and later we discuss (Student, School X).

> In my class the science teachers are not too helpful, whether physics, chemistry or biology. Even though they are always present when we do our practical they do not come to see what we are doing. (Student, School W)

Students also received support from their fellow students and laboratory assistants as the following quotations from students show:

> When you can't do an experiment and you see that someone has been able to do it you call him to come and help you. The teacher would still be in the laboratory. Sometimes we call the teacher. But we have seen that sometimes if we call our colleagues they are able to explain it to us better. This happened in the glass block and titration experiments. (Student, School Z)
>
> Sometimes we receive more help from fellow students that the teachers. When we need help during practical we call the teacher or our friends to help us. I understand it better with my friends. (Student, School W)

The comments from these students in the case study schools show that their teachers did not always give them the needed support during science practical activities. This lack of support is likely to breed frustration, which could result in dislike for science practical work. This study shows that generally, students had a positive attitude towards science practical work, but case study evidence shows that there are numerous problems with practical work in specific subjects.

The Role of Science Resource Centres in the Organisation of Science Practical Activities

Evidence from teachers' questionnaire shows that majority of teachers in satellite and SRC schools (74.0%) preferred using the SRCs for organising practical activities. This is not surprising since the SRCs have relatively better facilities for science practical work. What is surprising however is that a little more than half (54.5%) the teachers in satellite schools indicated that they preferred not to use the SRCs for science practical work even though 86.4% of teachers in satellite schools described their school laboratories as either equipped with some of the necessary materials/equipment needed for science practical (45.5%) or poorly equipped (40.9%). Evidence from the study shows that students in the case study satellite schools scarcely went to the SRCs for science practical activities. SSS3 students in school Z for example, had never set foot at the SRC whilst SSS3 students in school Y went to the SRC during the first term of the first year only. The HODs of schools W and Z threw some light on why they were not taking their students to the SRCs.

According to the HOD of school Z which is a less-endowed school, students were supposed to go to the SRC which was a distance of about 20 km from the school for their science practical activities. This is because the district has no SRC. It was however, not convenient for teachers to take a few students to the SRC to spend the whole day each week. Even though a bus from the SRC picked students of school Z they had to pay the fuel bill as well as the cost of consumables for biology and chemistry practical activities. In addition, students had to pay ¢5,000 a term as commitment charges before they were given access to the SRC. Most often when students got to the resource centre, the teachers were not ready for them, and sometimes they went there only to find students of that school occupying the SRC laboratories. The HOD thought that transporting 15 students to the SRC was not cost effective and hence preferred borrowing items from the centre instead to organise practical activities for students in the school. Items the school normally borrowed for physics for example were cells, metre rule, calorimeters, vernier callipers, weights, micrometer screw gauge etc. However, interviews with the students revealed that these items were borrowed during preparations towards the final WAEC examinations and not for regular practical activities.

The views of the HOD of school W, classified as a well-endowed school was not very different. When asked why students from school W were not going to the SRC, he replied

> Personally I think everything the SRC have we have them here. So what is the point in taking students there? Personally, I see it as a waste of time. Sometimes what you want them to go to the SRC to see, the teachers there can't organise it for them. Rather, simple experiments as we can organise here is what they organise for them. So what is the point in going there? (HOD, School W).

According to the HOD of school W, in physics for example, there are so many things, which can be demonstrated, based on the resources at the SRCs. So if that was done and the SRC teachers announce to the schools that they had set up very interesting experiments like the use of the cathode ray oscilloscope and others to attract students to the centre, then they in turn will send the students there. However, the normal practice was for the resource centre teachers to ask the schools to give them a list of experiments they wanted their students to perform. The HOD of School W felt that their school could organise all the basic practical activities in science. So if students were going to the SRC for practical activities it should be for the ones they could not organise in their school. Like the HOD of school Z, he also complained that sometimes the teachers at the resource centre were not ready for the students and this led to waste of time. Interview with students in school W confirmed this.

> To me it was a waste of time. The teachers there didn't like us. They always compare us with the students *in their school* [italics added] that they are better than us. They didn't devote their time to us. They only come and do anything they like. But one of the biology teachers was very good to us but not the physics and chemistry teachers. The chemistry and physics masters were not all that helpful to us (Student, School W).

However, unlike school W which claimed that their laboratories were reasonably well equipped for basic experiments, the HOD of school X considered to be well-endowed complained that his school laboratories was poorly equipped and they depended very much on the SRC in the school for facilities for practical activities. Fortunately, for this school, the SRC is situated in the school. With students from other schools not patronising the centre, the SRC in school X has virtually become the school's permanent laboratories. A similar situation existed in school Z that had an SRC.

The HOD of school Z who was also the Coordinator of the SRC lamented that satellite schools had not been patronising the centre. According to him, one SSS had visited the SRC twice and also a private SSS has been there twice since the establishment of the centre some four years ago. Another SSS had decided to create its own science laboratory and so does not patronise the centre. He felt that because some of the schools were not offering elective science subjects they were not keen in patronising the centre.

An interview with the Coordinator of the SRC located in school X was quite revealing. The Coordinator was asked why school W was not patronising the centre. In his reaction, he confirmed the fact that the two schools which were supposed to patronise the centre had complained that any time they went to the centre the whole of that day was wasted since they could not attend classes for the other subjects they offer in their own schools. According to him, the problem was with the time table. When the students go to the centre, the first three periods was given to chemistry, the next three periods for biology and the last three for physics. The students were therefore divided into three groups and they rotated over the three practical sessions. Students therefore, virtually spent the whole day at the centre. Their own school time table was therefore disrupted at least for that day. Students however, offer other subjects in addition to science. Initially the students were going to the centre once every week but they realised that it was affecting their participation in other school subjects. To address this problem the Coordinator said:

> we met and agreed that it must be fortnightly. And then the fortnightly too the last time it collapsed was when they were having their mock. A whole lot of issues cropped up and fitting it into their time table was not done (SRC Coordinator, School X).

A new arrangement where in term one SSS3 students could go to the centre followed in term two SSS2 students, SSS1 in term 3 so that they could work it into their time tables also encountered problems. The Coordinator conceded that the well-endowed schools, which were supposed to patronise the centre could conduct most basic experiments in their schools. The Coordinator felt that in establishing the resource centres, the MOE should rather have brought equipment, which were not common, and those, which were expensive to the centre. This could have been placed at the centres so that students could go and use those equipment for experiments which they would not be able to perform in their own schools. If going to the centre was to perform what the teachers called "routine experiments" then it seems that in the well-endowed schools, the idea of the resource centre is not necessary, since they have most of the necessary equipment and so could be independent of the SRCs in terms of practical activities. The two schools, which were to go to this particular centre, were well-endowed and as at the time of doing the research both schools had completely stopped going to the centre. The last school stopped almost a year before this study. In any case, this study has established that schools did not put much emphasis on practical work at least in the first two years at the senior secondary school. Patronage of the centres then does not arise during this period. Another problem facing the centres according to the Coordinator was money.

> The ministry gives three million cedis a year for the running of the SRC bus. But tyres and servicing is expensive. Sometimes one servicing may cost about one million cedis and there are other problems. So for fuelling and serving three million cedis for the whole year is inadequate. And if we have 15 students, going there to pick them to come and perform experiments is not economically wise (SRC Coordinator, School X).

According to the Coordinator a packet of filter paper costs ¢26,500, so if one is performing an experiment on filtration alone and there are 45 students that packet of filter paper will be used up. Filtration alone plus other components cost so much yet students were asked to pay only ¢5,000 per term. For example, when the centre in school X was established, the Ministry of Education brought 20 burettes and those ones were of the glass type and so most of them had jammed according to the Co-ordinator. Meanwhile one burette cost about ¢ 300,000 and a pipette about ¢100,000 not to talk about flasks, chemicals and other equipment. Even though the amount paid by students was woefully inadequate, according to the HODs, students were not prepared to pay more. This has therefore put a lot of financial burden on the centres. According to the Coordinator

We had a complaint from one of the well-endowed schools. They said that at their school if they are performing an experiment if it is a fowl each student is given one. So they were expecting that when they came here each student would be given a separate set up. Each fowl is ¢15,000 so if in the whole term students pay just ¢5,000 it means that for one practical session we must find money from elsewhere.

(SRC Coordinator, School X).

The SRCs are supposed to be very well equipped centres but according to the Coordinator even in terms of everyday practical activities students were expected to perform, the centre was not equipped with adequate number of apparatus. It was therefore not possible for the students to work individually when they go to the centre. Even with simple titration, students had to work in groups and even though when students work in groups they share ideas, the Coordinator thought it was necessary for them to work individually in order to build confidence in handling practical activities unaided during the WAEC practical examination. According to him, when students do group work they build up group confidence so that when they are on their own they can't work independently". The Coordinator thought that maybe SSS1 and SSS2 students could be made to work in groups then later in SSS3 they should work individually. According to the Coordinator the centre did not have most of the chemicals for functional group analysis. The Coordinator enumerated several other problems. For example, an equipment like DL plus, brought to the centre by Philip Harris International was not suitable for the kind of practical work conducted in schools. In biology, bio- viewers supplied by Philip Harris International did not have the accompanying slides. The same goes for the overhead. Some of the chemicals were inadequate and most of the dyes had been thrown off. The kit for soil experiments had been depleted and there was no local market where they could buy from. According to him, physics equipment were available but inadequate. Stop clocks brought to the centre were such that once the battery runs down that was the end of the instrument even if new batteries were fitted. The centre had only two computer inter-phases, so if there were many students and the computer must be used to plot graphs or perform experiments it was not possible. The six computers at the centre were inadequate and most of the programmes on them were outmoded.

Asked whether the Ministry of Education had been replenishing the stocks the Coordinator replied

> No no no since they supplied they haven't bothered to change them or improve upon them. Because the pH meters for example has a life span. After some time the sensitivity reduces. The chemicals also have a life span. These things were not taken into consideration in setting up the laboratories (SRC Coordinator, School X).

Another problem was continuity. In the words of the Coordinator

> If you use the DL plus in the secondary school and you go to the universities they don't have it. So in my view it is poor planning. There must be continuity so that if you go to the university you must find these equipment there. But after spending time the students go to the university and don't have access to such equipment it is of no benefit to him/her. Some of the equipment don't have sensors. (Coordinator, SRC in school X)

After going through the resource centre practical manuals the researcher found that most of the experiments were for demonstrations and the teaching of concepts. Very few experiments were related to practical activities suitable for the science curricula and WAEC practical examination. However, the latter are the kind of practical activities teachers and students were interested in. According to the Coordinator, the activities in the manuals were not based on the SSS science syllabuses but were meant to help science teachers use the science equipment package from Philip Harries International, to teach at the centres. There were three volumes of the manual one for each subject. Table 23 gives an idea of the nature of practical activities covered in the SRC manuals. The practical activities are in three categories:

(a) Student practical activities related to the SSS syllabus

(b) Practical activities for teaching purposes (demonstrations)

(c) Practical activities of general interest (project work)

Table 23

Distribution of practical activities in SRC manuals

	Practical activities to be done by students related to the syllabus	Practical activities for demonstration	Practical activities of general interest
Physics	48 (36.9)	75 (57.7)	7 (5.4)
Chemistry	10 (15.4)	45 (69.2)	10 (15.4)
Biology	32 (32.7)	66 (67.3)	0 (0)

Percentages are in brackets

The table shows that practical activities designed for teaching purposes or demonstrations by teachers in all three subjects were higher than those that students were expected to perform as part of the practical activities for the SSS science programme. For example, chemistry has only 15.4% of the activities for students to perform whilst the physics and biology manuals contain just about a third of such practical activities. This means that the activities in the manuals, and hence the practical activities to be conducted at the SRCs were more for demonstration purposes than individual or group practical activities to be performed by students. Given the time constraint teachers complained about, and the fact that students rarely performed practical activities in the lower forms, one wonders whether teachers would like to spend time at the SRCs doing demonstrations.

No wonder there was a very low patronage of the SRCs by the satellite schools. The sustainability of the concept of the SRC as centres where students could go for science practical activities to supplement what was being done in schools looks unfulfilled.

In summary, what the findings from the analysis of the role of SRCs show is that teachers' and students' did not patronise the SRCs as expected. This situation make schools that host the SRCs benefit a great deal from the centre as the centres have virtually become their permanent laboratories. Teachers in SRC schools were able to borrow almost all the apparatus required for their practical activities due to proximity. Even though, the SRCs are better equipped than most school laboratories, if some teachers do not usually conduct practical activities in the lower forms because of time constraint, then they will definitely not use the centres. Another important element is the value and concern teachers attach to going to the SRCs. The findings suggest that due to logistic problems and the time "wasted" at the centres due to the problems already discussed, teachers felt that it was not worth taking students to the centres only for them to undertake what they described as "routine experiments" which they could do in their own schools. These factors conspire with time tabling problems to make the SRCs not play the required role of supporting practical activities particularly in satellite schools.

Views on Improving the Organisation of Science Practical Activities

Teachers from both SRC and satellite schools expressed similar views on how the organisation of practical work could be improved in their schools. Teachers whose schools did not have official times for science practical activities on their time table felt that periods should be officially allocated on the time table for practical lessons. According to them, if this is done, teachers would be mindful of the fact that some periods were specifically allocated for practical work and this could minimise the use of all periods for the teaching of content only. Some teachers suggested the allocation of two hours per week for practical work.

A number of the teachers also mentioned that qualified laboratory assistants should be posted to their laboratories to assist them organise practical work for students. It seems the issue of laboratory assistants is a real problem, which needs to be addressed since teachers need support in organising practical activities for their students.

The issue of equipment and materials came up quite strongly. Teachers were of the view that school laboratories must be supplied with equipment such as microscopes, gas cylinders and accessories, mounted needles and permanent slides in plant and animal physiology, histology, and mosses, and the provision of a standard manual for practical activities. Also refrigerators must be supplied to the laboratories to keep some materials like enzymes under favourable conditions. Chemical reagents and preservatives must also be supplied. Equipment such as the air conditioners, ovens and incubators, which are not functioning, must be repaired. Deionizers must be provided to enable students work with distilled water. Outmoded equipment in schools should be replaced with modern ones. Teachers also felt that the organisation of science practical activities could be improved if the chemicals that are getting exhausted are replaced with new ones.

CHAPTER 5

SUMMARY, CONCLUSION AND RECOMMENDATIONS

Overview of the Research Problem and Methodology

In this concluding chapter, the most important findings are highlighted, and some generalizations are offered that it is hoped will focus attention on critical issues for curriculum developers, Ministry of Education, Ghana Education Service and the West African Examination Council.

This study sought insights into science practical work in Ghanaian SSS using schools in the Central Region of Ghana. This was done by providing descriptive, inferential as well as explanatory information on students' perception of their psychosocial laboratory environments; their attitudes to science practical work; teachers' views on the role of science practical work and how it is organised. The study was done in two phases.

Phase one involved a quantitative study that compared the means on attitude and perception variables of students in satellite and SRC schools. The first phase also covered science teachers' views on the role and organisation of science practical work in schools. This was achieved by employing a survey. After the macro level analysis of the data generated in phase one, phase two of the study used interviews and observation in four selected case study schools to gain deeper insights into issues and generalizations about science practical activities that emerged from the survey.

Summary of Key Findings

Factors Influencing students' Perception of their Science laboratory Psychosocial Environment

It was found in this study that more than one factor influenced students' perception of their psychosocial science laboratory environment. The study identified four factors that underlie students' perception of their psychosocial laboratory environment. These are:

(a) supply material environment

(b) reliable material environment

(c) integration, and

(d) supervision.

There were two types of material environment, one on the availability and adequacy of science equipment and materials and the other, the reliability of such equipment and materials when used in science laboratories. Supply material environment, which refers to the availability and adequacy of science equipment and materials, dominated students' perception of their psychosocial environments. Supervision, which has not yet been reported in the literature, was found in this study to be an important factor influencing students' perception of their laboratory environment.

Also, even though integration as a factor influencing students' psychosocial perceptions of their laboratory environment has been reported in the literature, both supervision and integration are positive dimensions that appear to influence students' views of their laboratory environments in both satellite and SRC schools.

The finding was that students' general perception of their science laboratory environments in both satellite and SRC schools were positive but significantly different in favour of students in SRC schools. The significant difference in perception was due to the different material environments in the two school types.

Factors Influencing Students' Attitude towards Science Practical Activities

The study identified three factors that influence SSS students' attitude towards science practical work. These are:

(a) learning tool,

(b) interest, and

(c) equipment.

Among the three scales, learning tool was found to be the dominant factor when both satellite and SRC schools were combined. There was however, no significant difference between students in satellite and SRC schools on this dimension.

The study also found that generally, students' attitude towards science practical activities in both satellite and SRC schools were highly positive but significantly different. Students in SRC schools had a significantly more positive attitude towards science practical work than their counterparts in satellite schools. The attitude of students in SRC and satellite schools however, differed significantly on the interest and equipment dimensions in favour of students in SRC schools.

Associations between Students' Attitude and Perception

Generally, the attitude of students towards science practical work in SRC and satellite schools was not related to their perception of their psychosocial science laboratory environment.

Teachers' Views on the Purpose of Science Practical Work

Teachers' views on the purpose of science practical activities were mainly that it enables students understand science theory taught in the classroom and helps in the acquisition of attitudinal skills by students. Another finding in this study was that students had virtually no opportunity to identify their own problems to solve, or play a role in the development of appropriate experiments and subsequent interpretation of data.

Organisation of Science Practical Activities in Schools

Practical activities were not organized very regularly for students in the schools studied, particularly, when students are in SSS1 and SSS2. However, attempts were always made in the final year (SSS3) to make up somehow for practical work neglected in SSS1 and SSS2 to enable students take the WAEC science practical examinations.

In the organisation of science practical activities, students were not given the opportunity to use laboratory based practical activity to solve problems, construct relevant science knowledge on their own, undertake scientific investigations, and promote inquiry in the first two years of their science programme. Most of the practical activities were organised to verify known scientific concepts and laws. This situation has come to be entrenched in the schools as a result of many constraints, the major ones being time, overloaded curricula, lack of equipment and large class sizes.

The study also found that time allocated for practical work differed from school to school. In some schools, there were no periods at all allocated for practical work on the official school timetable. Teachers therefore, conducted practical activities as and when they deemed it necessary. Even where practical periods were fixed on the timetable, teachers normally used them to teach science theory.

The study also found that teachers in both satellite and SRC schools asked their students to work in groups of four or five on the average during science practical work. Group work took place in schools with large class sizes of 50 or more, as well as in those with small class sizes of 15. The key determining factor for teachers' using group work was inadequate equipment and materials as well as large class sizes in both satellite and SRC schools.

Support given to students when science practical activities were organised by teachers differed from one science subject to another, and also from one school to another depending on teachers' attitude and workload. The study found that apart from the science teacher, students received some support from their fellow students and laboratory assistants.

This study found that very few schools undertook journeys to SRCs, as such journeys were considered by majority of the schools as not cost effective and time wasting by science teachers and HODs. Teachers in satellite schools preferred to make do with whatever is available in their schools and occasionally borrowed from other schools for the science practical activities their students engaged in.

Implications of Research Findings for Science Practical Activities at the SSS

The findings as summarised in this section have clear implications for policy regarding SRCs and the performance of laboratory based science practical activities as a curriculum requirement.

The finding that generally, students had positive perceptions of their laboratory environment and attitudes towards science practical work means that students are interested in science practical work in spite of all the problems they face. Science teachers could easily take advantage of the generally positive perception and attitude of students to organise and sustain practical activities in schools.

The finding that supply material environment (availability and adequacy of science equipment and materials) is a strong factor which distinguishes the psychosocial perception of students' in satellite and SRC schools suggests that to improve science laboratory environments in schools, priority attention needs to be given to this factor. This is particularly important since equipment is also a factor that influences the attitude of students towards science practical work, and it is obvious that many schools do not meet the WAEC syllabus requirement of having well-equipped science laboratories for students to pursue the science programme. Science equipment must be repaired, and materials replenished from time to time to enable students continue to make use of them.

The finding that the dimension of supervision was a factor influencing students' perception means that teachers should pay more attention to support given to students. This is because the case study evidence shows that support given to students vary from one subject to the other, and from one teacher to another.

The finding that time allocation problems, and the use of groups, which results in most students not playing active roles in the performance of science practical work suggests that the organisation of practical work in the schools faces a lot of challenges. Even though the WAEC practical examination does not directly assess laboratory skills, these skills are necessary for the collection of raw data by students during the examination. Undoubtedly, the acquisition of laboratory skills will require laboratories equipped with all the necessary equipment for students to be able to practice and gain the necessary manipulative and recording skills. However, given the organisational problems associated with practical work in the schools, it should be possible for the WAEC not to put heavy emphasis on the collection and recording of raw data during science practical examinations. The focus of the examination could be on observation using photographs and graphs, processing and interpretation of data, experimental design, reasoning and problem solving skills, drawing of conclusions using appropriate diagrams, charts etc. The syllabus must therefore put emphasis on the use of demonstrations, simulations, video presentations, and science kits as necessary and sufficient means of teaching these skills at the SSS. Emphasis could be put on laboratory skills at the tertiary level for students who will pursue science at that level.

The findings that schools do not patronise the SRCs as expected, and even see it as a waste of time and resources, imply that the objective of setting up a centre where schools could undertake their practical work is not being achieved. The SRCs could however, be centres where teachers could borrow materials to organise science practical work in their own schools, send their students for demonstrations, and receive in-service training on how to effectively organise practical work.

Conclusion

Students' perception of their psychosocial science laboratory environments and their attitude towards science practical work were positive but significantly higher in favour of students from SRC schools. This seems to suggest that the use of facilities at SRCs for science practical work has a higher positive effect on students' attitude and perception. Students' perception of their psychosocial science laboratory environment is greatly influenced by the availability and adequacy of equipment in both SRC and satellite schools. Unfortunately, satellite schools do not patronise the SRCs, thus denying their students the benefit of using equipment from the SRCs. This study has however, provided information about what emphasis in the science laboratory environment will promote positive student attitudes and perceptions.

The purposes of the science practical activities organised by science teachers were mostly to verify known scientific concepts and laws taught in class. Much emphasis was put on the teaching of theory with very little attention paid to science practical work in the lower forms. Even though some practical activities were organised, most of it were delayed until students were in SSS3. Schools did not have equipment and materials which were commensurate with the number of students offering science, and in some cases instruments used for practical activities were faulty. Due to this state of affairs in the schools, in almost all science practical activities, students work in groups, and were rushed through them. Generally, there was poor supervision of students during science practical activities by their teachers. This did not give students the opportunity to get the needed exposure to laboratory training and practice.

The result was that there was inadequate exposure to science practical activities and supervised training of SSS science students over the three year period of science teaching and learning. This situation has arisen as a result of many constraints, the major ones being time, overloaded curricula, lack of equipment and large class sizes. These problems may account in part for students' weaknesses in WAEC science practical examinations.

Recommendations

The following recommendations are offered:

(1) Serious efforts must be made by the MOE to improve the material environment in SSS science laboratories to ensure that laboratory equipment and materials are available and adequate. Special attention

should be paid to satellite schools which usually lack materials and equipment in order to make the laboratories more attractive to students if the acquisition of manipulative and recording skills will continue to be emphasised by MOE and WAEC.

(2) The MOE, GES and Heads of Senior Secondary Schools should as a matter of urgency ensure that periods for science practical activities are officially allocated on the timetable in schools and that teachers use them to conduct practical activities for their students. More importantly, teachers' supervision of science practical activities must be monitored to ensure that students are given the needed exposure to laboratory training and practice.

(3) The MOE should adequately equip all schools for them to undertake basic practical activities and de-emphasis schools travelling to SRCs for routine practical activities. Teachers could borrow items from the SRCs or send their students to the resource centres for practical activities, which would be impossible for them to organise in their schools.

(4) In the long term, the MOE must think of de-emphasising the acquisition of laboratory skills. It should look at other lower alternative costs of doing science practical activities such as use of demonstrations, video presentations and other simulations which are effective but cheaper than laboratory-based practical work in promoting understanding of theory already taught or yet to be taught in class. This is because most practical skills such as observation, analysis and interpretation of data, problem

solving, experimental design, and drawing of conclusions could be acquired by students without the use of well-equipped laboratories.

Limitations of the Study

Despite the obvious advantages of integrating quantitative and qualitative data by the use of different methodologies, the two methodologies (quantitative and qualitative) are based on different assumptions. It is therefore possible that such different research techniques could produce different results.

The focus on four case study schools out of a total of eighteen schools places a limitation on the study. This was due to limited financial resources, and time at the researcher's disposal. Also, the purposive sampling procedure used to select case study schools decreases the generalisability of findings on practices in SSS in Ghana. This study will not be generalisable to all SSS in Ghana. The findings will however, serve as indicators of what may be happening in other SSS in the other regions of Ghana.

Finally, the study used students offering all three elective science subjects. However, it is possible that only one or two subjects may influence the perception and attitude of students.

Suggestions for Future Research

Throughout the research, some issues surfaced that relate to the topic of the study but which demand separate research effort to understand them further. In this section the outstanding issues arising from the study, which require further investigation, are presented.

(1) Evaluation of Science Resource Centres

One of the issues that surfaced in this study was the role SRCs are expected to play in the teaching and learning of science particularly, in supplementing the activities of satellite and less-endowed schools. As noted in Chapter 2, the activities of the SRCs have not been comprehensively evaluated since their establishment and the research findings point to ineffective SRCs.

Further research is needed to evaluate the SRCs to see the role it is playing now as against the expected objectives in order to fully redirect it. Issues about patronage, replacement of equipment, time tabling, cost to schools in using the centres as well as convenience and benefits to schools and students need to be researched into.

(2) Research into the Relationship between Practical Work and overall Performance in Science

Detailed analysis must be done to determine the relationship, if any, between performance in science practical examinations and the overall grades students obtain in each of the science subjects in order to determine whether in reality, lack of practical work has any significant effect on students overall grades.

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APPENDIX A1

EXCERPTS OF CHIEF EXAMINERS' REPORTS ON CANDIDATES' PERFORMANCE ON SSSCE BIOLOGY PRACTICAL EXAMINATIONS

The weaknesses include the following:

1. the quality of diagrams drawn were poor
2. labels of diagrams were either wrongly spelt or the guide lines did not touch the points appropriately
3. writing up of experiments were poorly done. In some cases the candidates had no idea at all as to what the experiment was about.

Both teachers and students have to put in more effort to bring about improvement in performance in examinations.

(Chief Examiner's Report, 1999, p. 7)

The major weaknesses noted in candidates' scripts included the following:

1. It was difficult for all candidates to explain the data provided for the graphs
2. Candidates were unable to derive practical value or ecological significance from the data provided for the graphs
3. Answers of candidates should be based on specimens provided only. In most candidates wrote on unobservable features. This implied that they answered the practical questions from the theory they have learnt. Such answers did not attract any marks
4. There were too many spelling mistakes which were punishable, especially, in the case of names and biological terms.

5. The standard of drawing still remains poor, and there is room for much improvement.

Teachers and students have to undertake more tutorials as a way of remedying these weaknesses.

(Chief Examiner's Report, 2000, p. 132)

Three main areas where candidates showed some weaknesses are:

1. Lack of understanding of the questions set.
2. Poor spelling of technical and scientific names.
3. Poor expression in English.

The standard of the paper compared favourably with that of the previous years. In line with the trend observed in the past few years however, the general performance of the candidates was poorer.

Candidates must read questions carefully to understand them before answering.

Teachers should have spelling drills on technical and scientific names with their students.

Students are encouraged to read storybooks to enrich their vocabulary.

(Chief Examiner's Report, 2001, p.115)

APPENDIX A2

EXCERPTS OF CHIEF EXAMINERS' REPORTS ON CANDIDATES' PERFORMANCE ON SSSCE CHEMISTRY PRACTICAL EXAMINATIONS

Titre values recorded by some candidates deviated greatly from those recorded by the Supervisors. The way some of them recorded their titre values gave an indication of their not having mastered the art of titration or mastered the requisite practical skills.

Some candidates did a lot of cancellations in their write-ups giving the impression that their writings were not based on their own work.

For question 2 most candidates were found wanting in the way they recorded their tests and observations. They either did not write the tests and observations at the time they were made and therefore forgot to write them or thought some of the points were not worth putting down.

Most candidates could not answer question 3 of the three alternative papers well indicating that they were either not taken through the activities or did not take them seriously.

Students should be taken through a lot of practical activities for them to acquire the requisite practical skills.

(Chief Examiner's Report, 1999, p. 15-16).

For question 2, some of the candidates did not follow the instructions and therefore could not present their results as required. The third question of all the three alternative papers as usual was poorly done. Answers provided by most candidates indicated that activities outlined in the teaching syllabus to be performed by candidates have not been given serious attention that they deserve. Candidates should be exposed to a lot of practical work to enable them acquire the requisite practical skills.

Attention should also be paid to the activities outlined in the teaching syllabus so that candidates would be able to answer the third questions satisfactorily.

(Chief Examiner's Report, 2000, p. 138)

The standard of the paper was comparable to that of previous years. However, the performance of candidates was not encouraging at all.

Students are advised to prepare adequately for the examination.

Teachers should endeavour to expose students to practicals so that they can acquire the necessary concepts and skills that are needed to pass the paper.

Teachers should try to teach the mole concept from the first principle to ease understanding.

(Chief Examiner's Report, 2001, p. 121)

APPENDIX A3

EXCERPTS OF CHIEF EXAMINERS' REPORTS ON CANDIDATES' PERFORMANCE ON SSSCE PHYSICS PRACTICAL EXAMINATIONS

It is suggested that students:

1. are taught report writing and how to state precautions taken to ensure accurate experimental results.
2. are taught how to use measuring instruments to measure accurately
3. desist from premature rounding-off of figures until the final answer is obtained
4. watch their arithmetic manipulation when solving problems.

(Chief Examiner's Report, 1999, p. 40)

The standard of the paper compared favourably with that of previous years. Candidates' performance is the same as last year. However, few candidates performed poorly.

1. Most candidates made deductions after obtaining only one reading from their experiments.
2. Candidates after writing the experimental values in the standard form, labeled the axes of their graphs wrongly.

(Chief Examiner's Report, 2000, p. 168)

Candidates need to be careful in recording their distance measurements. They confused the units "cm" and "mm".

Many candidates were unable to take protractor readings accurately. Protractor readings like 15.0°, 25.0 °, 35.0 °, were erroneously recorded as 10.5 °, 20.5 °, 30.5 ° etc. Also instead of the unit (o) they stated (^{0}C).

Candidates had problems in plotting figures like 10.5, 20.5, 30.5 etc. For these values they instead plotted 15, 25, 35 etc. Candidates continue to choose very awkward scales difficult to plot with. Scales such as 1:2; 1:5; 1:10 are strongly recommended.

Candidates should choose workable scales for their graphs.

Teachers must expose candidates to a lot of practicals and teach them how to take readings or measurements.

(Chief Examiner's Report, 2001, p. 153)

APPENDIX B

KREJCIE AND MORGAN'S TABLE FOR DETERMINING THE SIZE OF A RANDOM SAMPLE

N	S	N	S	N	S
10	10	220	140	1200	291
15	14	230	144	1300	297
20	19	240	148	1400	302
25	24	250	152	1500	306
30	28	260	155	1600	310
35	32	270	159	1700	313
40	36	280	162	1800	317
45	40	290	165	1900	320
50	44	300	169	2000	322
55	48	320	175	2200	327
60	52	340	181	2400	331
65	56	360	186	2600	335
70	59	380	191	2800	338
75	63	400	196	3000	341
80	66	420	201	3500	346
85	70	440	205	4000	351
90	73	460	210	4500	354
95	76	480	214	5000	357

N	S	N	S	N	S
100	80	500	217	6000	361
110	86	550	226	7000	364
120	92	600	234	8000	367
130	97	650	242	9000	368
140	103	700	248	10000	370
150	108	750	254	15000	375
160	113	800	260	20000	377
170	118	850	265	30000	379
180	123	900	269	40000	380
190	127	950	274	50000	381
200	132	1000	278	75000	382
210	136	1100	285	1000000	384

Notes: N = Population size; S= Sample size

Source: Krejcie and Morgan cited in Cohen, Manion & Morrison, p94

APPENDIX C

ATTITUDE TOWARDS SCIENCE PRACTICALS (ASP)

Questionnaire for science students in satellite and SRC schools

Directions

This questionnaire contains statements about attitudes to science practicals.

There are no "right" or "wrong" responses. Your feelings about each statement is wha is important. Tick the appropriate column corresponding to your feelings about the

Be sure to respond to all items. If you change your mind about your response to an item, just cross it out and tick another.

Some statements in this questionnaire are fairly similar to other statements. Don't worry about this. Simply give your opinion about all statements.

	Statements	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
1	I like working with science equipment during science practicals					
2	I wish we don't have science practicals so often					
3	Science practicals help me to understand the theory taught in class					
4	I don't like science practicals					
5	I would like to have more exposure to science equipment during practicals					
6	I like working with science equipment despite the problems I have when using them					
7	Science practicals make me appreciate science better					
8	Science practicals help me to understand what I learn in the classroom					

	Statements	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
9	Writing up science practicals is a very useful exercise					
10	Science practicals help me acquire a scientific skills					
11	Science practicals help me to learn science better					
12	Science practicals are boring					
9	Writing up science practicals is a very useful exercise					
10	Science practicals help me acquire a scientific skills					
11	Science practicals help me to learn science better					
12	Science practicals are boring					
13	I like science practical write-ups after the experiment					
14	I understand science lessons better after doing science practicals					

BIO DATA

GENDER MALE ☐ FEMALE ☐

AGE ☐ years

NAME OF SCHOOL................................

APPENDIX D

SCIENCE LABORATORY ENVIRONMENT QUESTIONNAIRE (SLEQ)

Questionnaire for science students in satellite and SRC schools

Directions
This questionnaire contains statements about practices, which could take place at your school laboratory. You will be asked how often each practice

There are no "right" or "wrong" answers. Your opinion is what is wanted about what actually takes place during science practicals at your school laboratory

Think about how well each statement describes what happens at your school laboratory. Tick the appropriate column corresponding to what actually takes

Be sure to give an answer for each question. If you change your mind about an answer, just cross it out and tick another.

Some statements in this questionnaire are fairly similar to other statements. Don't worry about this. Simply give your opinion about all statements.
Remember that you are being asked how often (Never, Rarely/Not Often, Undecided, Often, Always) each of the following practices actually takes place

	Statements	Always	Often	Undecided	Rarely/Not Often	Never
1	At school we are taught the theory before we perform the practicals in the laboratory					
2	We have enough equipment in our school laboratory for practicals					
3	Experiments we perform in our school laboratories do not yield accurate results					
4	Laboratory equipment in our school are faulty					
5	The theories we learn during science lessons are not related to the practicals we do in our school laboratories					

	Statements	Always	Often	Undecided	Rarely/Not Often	Never
6	Our school laboratories have enough room for individual/group work					
7	Our school laboratory is an attractive place to work					
8	Teachers do not supervise what we do during practicals in our school laboratory					
9	Students are required to follow certain safety rules in our school laboratories					
10	Our teachers do not come round to supervise what we are doing during					
11	The equipment/materials students need for practicals are readily available in our school laboratories					
12	What we do in our school laboratory sessions help us to understand the theory we learn in class					
13	There is a recognised way of doing things safely in our school laboratories					
14	We are asked to perform science practicals in our school laboratories without any guidance					
15	We are supplied with all the equipment we need for our experiments in our school laboratory					
16	We don't get the opportunity to handle every equipment in our school laboratory					
17	We make use of the theory taught in class during science practicals in our school laboratories					
18	Laboratory equipment in our school give wrong results					

BIO DATA

MALE ☐ FEMALE ☐ AGE ....yrs

NAME OF SCHOOL..........................

APPENDIX E

QUESTIONNAIRE ON THE ORGANSISATION OF SCIENCE PRACTICAL WORK

(For science teachers)

This is a study, which seeks to find out issues connected with the organisation of science practicals in your school. Please tick the appropriate box or provide the information in the spaces provided. Your responses will be treated as confidential and used only for research purposes. Your identity is not required hence respond to the items as truthfully as possible.

SECTION A: BIO DATA

1. Gender: M ☐ F ☐

2(a) Educational Qualification...

2(b) What subject do you teach? (You may tick more than one)

Chemistry	
Biology	
Physics	
Integrated Science	
Other (Specify)	

3. In which subject do you teach science practicals in your school?

Chemistry	
Biology	
Physics	

4. How many years have you been teaching at the Senior Secondary School level? ☐

SECTION B: ORGANISATION OF SCIENCE PRACTICAL WORK

5. Do you have a Science Resource Centre in your school?

Yes ☐ No ☐

6(a) Do you give support to your students when they are engaged in science practicals?

Yes ☐ No ☐

(b) If Yes, what kind of support do you give?

....

....

....

(c) If No, why don't you give support?

....

....

....

7. Who do your students receive support from during science practicals?

(You may tick more than one)

	Tick
Laboratory assistants	
Fellow students	
Science teacher	
Other(specify)	

8. Who do your students receive **most support** from during science practicals?

(You may tick more than one)

	Tick
Laboratory assistants	
Fellow students	
Science teacher	
Other(specify)	

9(a) Do you have an approved textbook for science practicals at SSS level?

Yes ☐ No ☐

9(b) Do your students perform science practicals by using a science practical textbook(s)? Yes ☐ No ☐

9(c) If Yes what is/are the name(s) of the textbook(s)

....

....

....

....

9(d) If No, what do they use for their science practicals?

....

....

....

....

....

....

....

10. What difficulties do you have in organising science practicals?

....

....

....

....

....

11. What difficulties do your students have with science practicals?

....

....

....

12(a) Do you have periods officially allocated on your timetable for practicals?

Yes ☐ No ☐

12(b) How many periods are officially allocated on your timetable for practicals?..........

12(c) In your opinion are practical periods allotted on the timetable adequate?

Yes ☐ No ☐

13. The science practicals my students perform are:

(Please respond to each item)

	Always	Very Often	Often	Never/ Rarely
Designed by me (the science teacher)				
Taken from textbooks				
Taken from pamphlets				
Taken from WAEC past questions				
Other (specify)				

14. During science practicals students:

(Please respond to each item)

	Always	Very Often	Often	Never/ Rarely
Design their own experiments and carry them out				
Follow instructions to carry out experiments given to them				

15. How many periods on the average do you use for science practicals each week?

No. of periods	Tick
1 period	
2 periods	
3 periods	
4 periods	
Other Specify	

16. During the period allocated for science practicals each week students

(Please respond to each item)

	Always	Very Often	Often	Never/ Rarely
are able to complete their science practicals and write-up in the laboratory report before they leave				
are able to complete their science practicals in the laboratory but do the write-up after they leave				
do not complete their science practicals and have to continue at another time				

17. During science practicals, students **usually** work in groups of ……

18. Which laboratory/environment do you use for your science practicals?

    (You may tick more than one)

    Science Resource Centre laboratory ☐ School laboratory ☐

    Classroom ☐ Other (Specify)…………………………………

19. How many periods a week, on the average ,do your students spend on science practicals? ……………

20. How frequent do your students go to the Science Resource Centre laboratory for practical work?

Frequency	Tick
Once a week	
Once every 2 weeks	
Once a month	
Once a term	
Twice a term	
Rarely	
Other (specify)	

21(a) Do you prefer to use the Science Resource Centre laboratories for your practicals? Yes ☐ No ☐

(b) If Yes, why do you prefer it?

....

....

(c) If No, why don't you prefer it?

....

....

How will you describe the school science laboratory?

		Tick
a	Equipped with all the necessary materials/equipment needed for science practicals	
b	Equipped with some of the necessary materials/equipment needed for science practicals	
c	Equipped with less than the necessary materials /equipment needed for science practicals	
d	Lacks almost all the necessary materials/equipment needed for any meaningful science practicals	

Which laboratory are you describing? **(Please tick only one).**

Science Resource Centre laboratory ☐ School laboratory ☐

22. On the average, how often do you use the following environments for teaching science? **(Please respond to each item).**

	Always	Very Often	Often	Rarely/ Never
Classroom				
Laboratory				
Field (for field work)				

23. On the average, how often do your students **perform** science practicals?

Frequency	Tick	No. of Hours
Twice a week		
Once a week		
Once every two weeks		
Once a month		
Other (specify)		

24. Generally, how often do you have discussions on science practicals **before** students undertake them?

Frequency	Tick
Always	
Very often	
Sometimes	
Rarely	
Never	

25. Generally, how often do you discuss experimental findings/results with your students **after** science practicals?

Frequency	Tick
Always	
Very often	
Sometimes	
Rarely	
Never	

26. Generally, how often do you stay with your students when they are engaged in science practicals?

Frequency	Tick
Always	
Very often	
Sometimes	
Rarely	
Never	

27. Do you have a laboratory assistant to help you with the organisation of science practicals? Yes ☐ No ☐

28. What do you wish can be done to enable you improve upon the organisation of science practicals in your school?

....

....

....

....

....

APPENDIX F

QUESTIONNAIRE ON THE ROLE OF SCIENCE PRACTICAL WORK (QRSP)

(For science teachers)

This is a study, which seeks to find out the role of science practical work in the teaching and learning of science. Your responses will be treated as confidential, and used only for research purposes. Your identity is not required hence respond to the items as truthfully as possible.

Please tick the appropriate box or provide the information in the spaces provided.

SECTION A: BIO DATA

1. Gender: M ☐ F ☐

2(a) Educational Qualification..

2(b) What subject do you teach? (You can tick more than one)

Chemistry	
Biology	
Physics	
Integrated Science	
Other (Specify)	

3. In which subject do you teach science practicals in your school?

Chemistry	
Biology	
Physics	

4. How many years have you been teaching at the Senior Secondary School level ☐

SECTION B: ROLE OF SCIENCE PRACTICAL WORK

5. Do students design experiments individually or do they do it as a class/group

(You may tick more than one)

Individually ☐ As a Class ☐ In groups ☐

Other(specify)...

6(a) Do you allow your students to design and try their own personal experiments during science practicals?

Yes ☐ No ☐

(b) If Yes, why do you allow it?

....

....

....

(c) If No, why don't you allow it?

....

....

7. What in your view is the essential function of science practicals in the teaching and learning of science?

....

....

8. How often do the following processes feature in the kind of science practicals students perform in your class? **(Please respond to each item)**

	Always	Very Often	Often	Rarely/ Never
Students identify their own problems for scientific investigation through experiments				
Students select their own variables for experiments				
Students assemble their own selected experimental apparatus				
Students collect data				
Students record data				
Students analyse data				
Students present experimental findings				
Students interpret their findings				
Students justify the interpretation of their findings				

9. **Rank** the following reasons for doing science practicals from 1(for the most important reason) to 10 (for the least important reason).

	Rank
For finding facts and arriving at new principles	
To use science practicals to clarify theory	
To satisfy the science syllabus and WAEC requirements	
To encourage accurate observation	
To enable students pass their final examination	
To verify facts and principles already taught	
To arouse and maintain interest in science	
For students to develop specific manipulative skills	
To enable students understand the theory better	
To practice looking for problems and seeking ways to solve them	

10. How frequent are the following science practicals performed by your students

Types of science practicals	Always	Very often	Often	Rarely/ Never
Practicals to verify theory already taught in class				
Project work designed by students based on a problem of				

students develop scientific attitudes				
Practicals designed to help students develop laboratory skills				

11. How often are the following skills emphasized in the science practicals you organise for your students. **(Please respond to each item)**

Skills	Always	Very Often	Often	Rarely/ Never
Objectivity				
Problem formulation				
Manipulating				
Skills				
Initiative				
Observing				
Integrity				
Experimental design				
Predicting				
Drawing conclusion				
Hypothesizing				

12. Rank the following skills in terms of importance from 1 (for the most important) to 10 (for the least important).

	Rank
Objectivity	
Problem formulation	
Manipulative	
Initiative	
Observing	
Integrity	
Experimental design	
Predicting	
Drawing conclusion	
Hypothesizing	

APPENDIX G

FOCUS GROUP INTERVIEW PROTOCOL FOR INTERVIEWING SCIENCE STUDENTS

Name of school.....................................Type.......
No. of streams................
Date............................Time..........

Practical Notebooks

Let students present their physics, chemistry and biology practical notebooks from SSS1

In a discussion with them fill the tables for questions 1 and 2.

Q1 How many practicals have you done in science from form 1 up to now?

Subject	SS1	SS2	SS3	No. of times per week	No of weeks
Physics					
Chemistry					
Biology					

Q2. How many of these practicals were marked?

Subject	No. given			No. marked		
	SS1	SS2	SS3	SS1	SS2	SS3
Physics						
Chemistry						
Biology						

Q3(a) How often do you discuss what you are going to do in practicals before you do it?

(b) Do you discuss your findings, mistakes and difficulties after you have done it?

(c) How helpful are your teachers when it comes to science practicals?

Q4(a) What is it about practicals that you like? Talk about physics, chemistry and biology separately

(b) What is about practicals that you don't like? Talk about physics, chemistry and biology separately

Q6 How do you see your science laboratory in terms of equipment/material, space, support (laboratory asst., fellow students), integration and supervision (teacher).

Q7(a) If students don't do well in science practicals in your school, what will you attribute it to?

(b) Which of the science practicals are you confident about? Why? Talk about physics, chemistry and biology separately

Q8(a) Why do you work in groups?

(b) What are the advantages and disadvantages of working in groups during practical work?

Q9(a) How many times have you been to the science resource centre? Is going to the science resource centre useful?

(b) What are the problems?

O10 Do you think you would have been better off doing practicals, if you had attended a different school? Explain.

APPENDIX H

SEMI-STRUCTURED INTERVIEW PROTOCOL USED TO INTERVIEW HEADS OF DEPARTMENTS

1. Do you have a time table for practical work?
2. What problems do you have with the students when it comes to science practical work?
3. Do you use practical activities to help them understand the theory?
4. Do you teach practical work as a basis for the theory work or you teach the theory and you let students go and verify
5. How often do you have practical work?
6. Do students do their write-ups in the laboratory?
7. How much emphasis is put on practical work?
8. What is your students attitude towards practical
9. Are the students aware of what they are to do or not to do in practical work?
10. Your students say they have not been going to the SRC. What do you say about it?
11. What reasons do you have for students not doing practical work in forms 1 and 2?
12. What purpose does practical work play in the teaching and learning of science?
13. Do you have enough apparatus for practical work as a science resource centre school?

14. In the school's own laboratory do you have enough equipment for practical work?

APPENDIX I

SEMI-STRUCTURED INTERVIEW PROTOCOL USED IN INTERVIEWING SRC COORDINATORS

1. I have talked to students in other schools and they don't know why they don't come here. What is your reaction?
2. When students come here, who teaches them?
3. How well equipped is the Science Research Centre, in terms of everyday practical activities?
4. What kind of experiments do students undertake at the Science Research Centre?
5. In a summary, what will you say are your impressions about the Science Research Centre?

APPENDIX J

SPECTRUM OF TEACHERS' VIEWS ROLE OF SCIENCE PRACTICAL ACTIVITIES

Q1. Why do you allow students to design their own practicals?

- To allow students to apply their own ingenuity and be able to explain or put their thoughts across in the form of the experiments
- For a limited time, beside the main time
- To encourage initiative, creativity and innovation
- Because it can lead to discovery learning
- Inadequate time to supervise individually designed experiments. It is only allowed during speech day exhibitions
- The constraint to complete the WAEC syllabus does not allow such practice

Q2. Why don't you allow students to design their own practicals?

- lack of equipment usually means experiments are specific
- Practical work guided by WAEC syllabus
- Inadequate space and equipment
- Because of limited number of science apparatus in the laboratory
- They do not have enough drive to carry out experiments on their own
- For the sake of safe handling of the equipment and also time
- This is because there is no time for such activities to take place.
- During science practicals, the students come there to perform the experiments I have for them but during their free period they come there to

perform their personal experiments because we have only 2 periods per week

- Because the time available is limited
- The problem of time. There is so much work to do that students cannot have time to design their own experiments
- They may go out of order and may end up not getting any meaningful scientific results
- To concretise concepts learnt and to afford the students opportunity to infer, manipulate equipment, graph, interpret, observe, calculate, predict, hypothesise and draw conclusions from a mass of data.
- The period for practicals is short. The nature of the final examination does not allow it. However, if a students comes out with his own work which is within the syllabus he is allowed to do it, but not during the practical period
- Because apparatus are few and expensive and delicate nature of some of the apparatus
- To be able to develop the attitude for research work
- experiments done are based on the topics taught in class
- We do only practical work guided by WAEC syllabus
- Lack of equipment usually means experiments are specific
- There will be confusion in the laboratory
- Because we have a time frame to cover before they take their final WAEC examination

Q3. What in your view is the essential function of science practicals in the teaching and learning of science?

- To help students understand the concepts better
- To present the principles and concepts in science in a practical way to help students use their hands in making objects. It also helps them to understand the concepts better
- To develop practical skills, collect, record and analyse data
- Enhances understanding and appreciation of the subject of science
- It makes students understand the theoretical aspect better
- To enable students understand the theory better and this aids teaching and learning
- Helps the students to visualise what is taught and have a feel of what is taught in theory. It enhances understanding
- It helps students them to understand concepts which are difficult to explain in the classroom
- it makes the abstract things real to students and makes learning easier
- Practicals enable students to understand the theory better, sustain their interest and develop their analytical skills
- Helps students to very facts and principles that are taught in class. It gives opportunity to students to seek ways of solving problems that are identified
- To understand concept and principles in physics and to be able to use their hands and imaginative power.

APPENDIX K

RESULTS OF TEACHERS' RANKING ON REASONS FOR ORGANISING PRACTICAL ACTIVITIES

	Reasons	mean	median	mode	Rank
1	For finding facts and arriving at new principles	6	7	9	Low
2	To use science practicals to clarify theory	3	3	1	High
3	To satisfy the science syllabus and WAEC requirements	7	9	10	Low
4	To encourage accurate observation	5	6	3	Medium
5	To enable students pass their final examination	7	9	9	Low
6	To verify facts and principles already taught	4	4	4	Medium
7	To arouse and maintain interest in science	5	5	5	Medium
8	For students to develop specific manipulative skills	5	5	5	Medium
9	To enable students understand the theory better	4	4	4	Medium
10	To practice looking for problems	7	8	10	Low

and seeking ways to solve them

In compiling this table all the responses were brought together and average values were worked out. Mean, mode and median values for each of the statements were compared, since each of the methods had a tendency to obscure some aspect of the data. The values wee placed as an order (order of means, order of modes, and order of medians). All three orders were then considered in allocation a high (1-3), medium (4-6), or low (7-10) rank for each statement. Thus low denotes that all three averaging methods gave a low rank.

APPENDIX L

EXCERPTS OF SCIENCE TEACHERS' VIEWS ON THE ORGANISATION SCIENCE PRACTICAL ACTIVITIES IN SRC SCHOOLS

Q1. Do you give support to your students? If yes, what kind of support do you give?

- I do give hints to students who are unable to proceed as a result of their inability to understand some points in the theory of an experiment
- Because of lack of laboratory assistants I often supply students with apparatus. I sometimes help them in focusing specimens under the microscope and also ask questions to help them verify certain principles and theories
- By explaining the theory behind the practical
- I move from bench to bench to see whether they are doing the right thing. At the beginning of the experiment I show them how they should go about it
- Demonstrating for them to see and assisting those who still can't perform after demonstration

Q2. Do your students perform science practicals by looking into a science practical textbook(s)? If yes, what do you use for their science practicals?

- Biology for SSS by GAST
- Biology Practical for SSS by Dan Dare

Q3. Do your students perform science practicals by looking into a science practical textbook(s)? If No, what do you use for their science practicals?

- They normally use past practical questions. Methods as described by some textbooks on certain topics are also used sometimes
- I give the students instructions to follow if nothing is given in the GAST such as dissection of the cockroach to study the alimentary canal. Use of WAEC past questions
- They use practical handout printed by the master in charge
- Printed hand out from the SRC manual
- From the textbook I use
- There is no practical textbook
- We follow the tips or experiments given in the GAST

Q4. What difficulties do you have organising science practicals?

- Lack of the required apparatus and equipment needed for some practicals. Time constraints - looking at the content of the syllabus and the number of periods available
- Because of the fact that I am the only teacher taking elective biology, my practical classes are large. The absence of a laboratory assistant makes the work extra difficult. Inadequate apparatus such a s microscopes
- Availability of practical equipment and reagents
- Problem of getting the right specimen

- Since they perform the experiment in groups of five the students make a lot of noise
- Limited time. Materials and equipment not available.
- In cases where apparatus or instruments are not available it makes such practicals difficult

Q5. What difficulties do your students have with science practicals?

- Students find it difficult to understand some basic principles. Most times they only get access to the laboratory when they get to upper forms. Inadequate apparatus/equipment in the laboratory causes students to always work in groups which at times is inconvenient to some students
- Because of the quantity of apparatus in the laboratory, students usually work in groups of three or four. This makes participation by all members of the group impossible
- How to handle the glassware and work independently
- Since the students perform the experiment in groups, with a limited time not all students get access to perform the experiments themselves.
- They fail to follow instructions
- Due to increase in the number of students making it difficult for each student having access to a set-up. Since they usually work in groups some students just observe without having a feel of it.
- Setting up the equipment fort the practical work in some experiments. Choosing a scale for graph work after they have collected their results or

data sometimes become a problem more so when the readings are in decimals.

Q6 Do you prefer to use the SRC laboratories for your practicals? If yes, why do you prefer it?

- Because some of the equipment needed for practical lessons are available
- There are new equipment. The apparatus of the SRC have been mixed with those of the school.
- Because instruments/apparatus are available
- Because that is where the apparatus and chemicals are kept
- It is equipped with some of the necessary materials needed for science practicals

Q7. Do you prefer to use the SRC laboratories for your practicals? If No, why do you prefer it?

- The school has most of the science equipment for physics practicals. Besides, the place cannot accommodate all the students at the same time.

Q8. What do you wish could be done to enable you improve upon the organisation of science practicals in your school?

- Recruit laboratory assistants. That periods should be allocated officially on the time table for practical lessons
- A laboratory assistant must be posted to the laboratory to assist me. Necessary equipment and materials must be supplied adequately to ensure that each student gets access to a microscope. Materials needed

include gas cylinders and accessories and filled with gas, mounted needles and permanent slides in plant and animal physiology, histology, mosses etc. A refrigerator must be supplied to the lab to keep some materials like enzymes under favourable conditions. Chemical reagents and preservatives must be supplied to the lab. Equipment such as the air conditioner, the oven and the incubator which are not functioning must be repaired.

- Allowances should be given to both science teachers and laboratory assistants to motivate them to do more practical work. Tutors and laboratory assistants should be made to go for check up every month since they deal with a lot of dangerous chemicals
- Organisation of science practicals could be improved if the chemicals that are getting finished are replaced with new ones. The glassware that are broken should be replaced so that every student will get his/her own apparatus to work with. A week to the day of the practicals, the experiment they will perform should be given to them. This will allow them to read about it and make them encounter fewer problems.
- Periods should be increased on the time table. Equipment available are outmoded so modern ones should be made available.

Materials needed for the practicals should be available. Companies should open up to accept students for excursions so as to raise the interest of the students on how these are applied on the field. Moreover, science tutors should be made to attend regular courses for upgrading.

APPENDIX M

EXCERPTS OF SCIENCE TEACHERS' VIEWS ON THE ORGANISATION

SCIENCE PRACTICAL ACTIVITIES IN SATELLITE SCHOOLS

Q6(b) Do you give support to your students? If Yes, what kind of support do you give?

- Fixing apparatus correctly. Manipulation of variables and equipment
- To mount their apparatus and to check if they are doing the right thing
- Helping in identification , drawing and labelling
- We help them during the set up where they have problems.
- Correcting wrong experimental procedure; checking and correcting faulty equipment I give support when I see that they may injure themselves or are likely to damage any of the apparatus
- Sometimes in setting up the apparatus especially in electricity experiments and in checking out some faulty equipment

Q9(c) Do your students perform science practicals by looking into a science practical textbook(s). If Yes, what do you use for their science practicals

Investigations in biology for tropical schools by Leslie R. Allen; SRC practical book

Q9(d) Do your students perform science practicals by looking into a science practical textbook(s). If No, what do you use for their science practicals

- Selected instructions from past questions and some books

- Practical Chemistry (SAMKOFSEL's series)
- Practical pamphlets
- The instructions are written on the chalkboard from a textbook being used by the teacher i.e. Practical Physics for schools and Colleges by Brendar O. Ahuche.
- Physics for SSS and past questions of the WAEC
- Instructions are written on the chalkboard
- Prototype experiments from past GCE and SSSCE examination papers; any experiments in any practical textbooks where the experiments fall within their required practical experience
- Design some of the experiments on my own.
- The students are given the theory behind the practicals and later instructed on how to go about the work at the laboratory

Q10 **What difficulties do you have organising science practicals?**

- Inadequate equipment
- Limited apparatus, temporary lab, small space, few chemicals available.
- Most of the equipment are out of use or are spoilt. Besides the lab is not spacious enough to accommodate all the students so they come to the lab in batches and work in groups. In the afternoons the lab is very hot to stay there for a long time
- Lack of biological specimen

The laboratory is poorly equipped, as such there is difficulty in obtaining specimen.

- No water in the lab. Tap does not flow
- We don't have apparatus. Even the few ones we have are not working.
- Large class sizes
- Not every equipment required is available and sometimes have to be borrowed from another school. Equipment may be available but limited in number and therefore there may be more students per group than desire
- No trained lab assistant
- Non-availability of chemicals for experiments; no permanent lab assistant
- Every bit of the preparation is done by me only since the school has no lab assist
- Some of the equipment are old and some cases faulty so have to check them before being given to the students. The experiments in some set-ups are not enough and students have to pair up.

Q11 What difficulties do your students have with science practicals?

- Inadequate equipment
- In most cases the setting-up of the equipment poses some problem besides drawing an inference or relating the work to a concept already taught.
- Understanding instructions to practicals. Correct way of writing laboratory report
- Interpretation and discussion of biological data is a problem due to maths problem

- Inadequate time to do a lot of practicals.
- Inadequate space and equipment
- In electricity for example, experiments many start with readings in turns but later there may be inconsistency and investigation has to be done by science teacher.
- Have to work in groups. Problem in accurately reading measuring instruments. Problem in plotting graphs using results.
- Students sometimes work with improvised equipment which may not be very efficient or reliable
- Because of the inadequate facilities in the school's lab, they find it difficult appreciating the importance of practicals

Q21(b) Do you prefer to use the SRC laboratories for your practicals?. If Yes, why do you prefer it?

The SRCs are better

Q21(c) Do you prefer to use the SRC laboratories for your practicals?. If No, why do you prefer it?

- The SRC cannot adequately cater for the large number of students
- Besides the accumulators that we go to collect from the SRC we have almost all the equipment so we want to save time by working in our physics lab.
- It wastes a lot of precious time since it involves transportation.
- This is because most of the apparatus there are just for demonstration not for exams

- Laboratories are small and teachers in charge teach the same item several times in the course of about two hours and this is very time consuming.
- Teacher accompanying students spend the whole day at the centre. Equipment used by students at the centre not available to students during final exams.
- Transporting the students to the SRC
- Most of the apparatus needed in science practicals are available at the centres

Q29 What do you wish could be done to enable you improve upon the organisation of science practicals in your school?

- A larger well equipped lab. A lab assistant solely for physics. More of my periods for practicals.
- Provision of more equipment like microscopes, dissecting kits etc in the lab.
- The use of SRC should be made possible
- A well stocked laboratory. Standard practical textbooks
- Supply more apparatus, Provide time for practicals
- The required number of science equipment has often been requested so that where possible the fewest number of students practicable woiuld handle any particular experiment at a time

- A textbook for science practicals. Reasonalbe class size. Adequate science equipment. Two hours allocated for practical work per week. Engagement of a trained lab technician.
- A qualified lab assistant; a distillation equipment or deionizer to provide enough distilled water; electronic balance; adequate equipment/materials

There should be a well balanced student-teacher ratio for effective organisation of science practicals.

APPENDIX N

RESULTS OF TEACHERS' RANKING ON SKILLS THAT ARE PROMOTED DURING SCIENCE PRACTICAL ACTIVITIES

	Skills	mean	median	mode	Rank
1	Objectivity	4	4	5	Medium
2	Problem formulation	5	5	2	Medium/High
3	Manipulative	5	5	4	Medium
4	Initiative	4	4	1	Medium/High
5	Observing	3	3	2	High
6	Integrity	6	6.5	6	Medium
7	Experimental design	5	5	7	Medium/Low
8	Predicting	7	8	8	Low
9	Drawing conclusion	7	7	9	Low
10	Hypothesizing	7	8	10	Low

In compiling this table all the responses were brought together and average values were worked out. Mean, mode and median values for each of the statements were compared, since each of the methods had a tendency to obscure some aspect of the data. The values wee placed as an order (order of means, order of modes, and order of medians). All three orders were then considered in allocation a high (1-3), medium (4-6), or low (7-10) rank for each statement. Thus low denotes that all three averaging methods gave a low rank, medium/low that there were two medium and one low etc.